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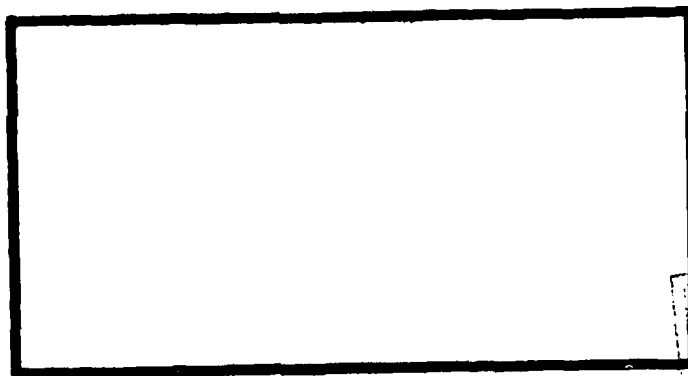
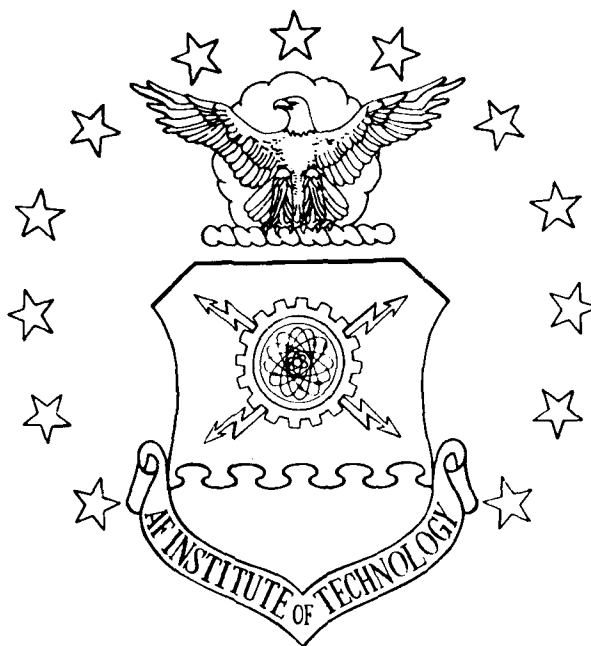
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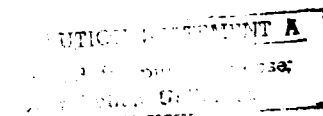
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UNITED STATES AIR FORCE  
AIR UNIVERSITY  
AIR FORCE INSTITUTE OF TECHNOLOGY  
Wright-Patterson Air Force Base, Ohio



A COST EFFECTIVENESS STUDY OF  
A CONSOLIDATED CORROSION  
CONTROL WORK CENTER

Donald R. Sellers, Major, USAF  
Frank L. Harmon, Captain, USAF

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Corrosion is a problem facing the U.S. Air Force at each of its installations located throughout the world in virtually every extreme of climate. Painting and washing of vehicles and equipment are accomplished almost daily by many work centers on every Air Force installation, combating corrosion to reduce or prevent the dollar and mission capability loss that corrosion represents. However, the effort to combat corrosion also has a dollar cost attached. In a time of inflation, rising costs, and diminishing defense budgets, all possibilities of reducing costs without impairment of the Air Force mission must be explored. The economic concept of economies of scale suggested to the authors that a reduction in the man-hour cost of washing and painting vehicles and equipment on Air Force installations might be realized through a consolidation of these activities under a single, specialized work center. The authors estimate man-hours and man-hour cost for such a work center and compare these with man-hour data drawn from selected Air Force installations. Man-hour savings are seen in washing activity but not in painting activity. However, the authors conclude that shortcomings in collected data prevent meaningful cost comparisons and conclusions therefrom.

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A COST EFFECTIVENESS STUDY OF  
A CONSOLIDATED CORROSION  
CONTROL WORK CENTER

A Thesis

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Logistics Management

By

Donald R. Sellers, BS  
Major, USAF

Frank L. Harmon, BS  
Captain, USAF

September 1976

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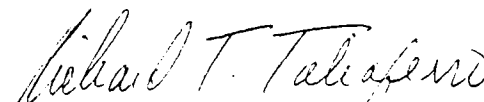
and

Captain Frank L. Harmon

has been accepted by the undersigned on behalf of the faculty  
of the School of Systems and Logistics in partial fulfillment  
of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 7 September 1976

A handwritten signature in cursive script, reading "Richard T. Taliaferro". The signature is written in dark ink and is positioned above a horizontal line.

COMMITTEE CHAIRMAN

## TABLE OF CONTENTS

	Page
LIST OF TABLES . . . . .	vi
LIST OF FIGURES . . . . .	viii
Chapter	
1. INTRODUCTION . . . . .	1
Problem Statement . . . . .	1
Background . . . . .	2
Justification . . . . .	3
Objective . . . . .	12
Research Question . . . . .	13
2. METHODOLOGY . . . . .	14
Introduction . . . . .	14
Definitions . . . . .	15
Population . . . . .	16
Design to Answer the Research Question . . . . .	18
Data Collection . . . . .	22
Sample Plan . . . . .	25
Assumptions . . . . .	26
Limitations . . . . .	27
3. LOGICAL ECONOMIES . . . . .	28
Work Center Primary Function . . . . .	28
Corrosion Control/Prevention Requirement . . . . .	32

Chapter	Page
Economies of Scale . . . . .	33
Summary . . . . .	35
4. CIVILIAN INDUSTRY DATA . . . . .	37
Introduction . . . . .	37
Data Presentation . . . . .	38
Curve Comparison . . . . .	43
Analysis . . . . .	56
5. BASE SAMPLE DATA . . . . .	65
Introduction . . . . .	65
Data Presentation . . . . .	65
Analysis . . . . .	72
Limitations . . . . .	75
6. CORROSION CENTER MODEL . . . . .	79
Capital Investment . . . . .	81
New Facility . . . . .	81
Model Description . . . . .	85
Analysis . . . . .	96
7. SUMMARY . . . . .	104
The Problem . . . . .	104
The Approach . . . . .	105
The Data . . . . .	106
The Model . . . . .	110
Conclusions . . . . .	111
Future Study Directions . . . . .	114

APPENDIXES	Page
A. STRUCTURED INTERVIEW . . . . .	115
B. MAN-HOUR STANDARDS, VEHICLE PAINTING . . . . .	118
SELECTED BIBLIOGRAPHY . . . . .	120

# LIST OF TABLES

Table	Page
1. List of Bases . . . . .	19
2. Factors Underlying Economies of Scale . . . . .	20
3. How Malfunction Codes . . . . .	21
4. Action Taken Codes . . . . .	24
5. Auto Laundry A . . . . .	44
6. Auto Laundry B . . . . .	45
7. Auto Laundry C . . . . .	46
8. Auto Laundry D . . . . .	47
9. Auto Laundry E . . . . .	48
10. Auto Painting Firm A . . . . .	49
11. Auto Painting Firm B . . . . .	50
12. Auto Painting Firm C . . . . .	51
13. Curve Equations . . . . .	54
14. Auto Laundry Capital Investment . . . . .	58
15. Auto Painting Firm Capital Investment . . . . .	62
16. Vehicle Data . . . . .	66
17. GSC 02000 Data . . . . .	68
18. HMC/ATC Combinations . . . . .	69
19. Man-Hours By Work Center and By Base . . . . .	70
20. Man-Hours By Combination and Base . . . . .	71
21. Comparative Annual Facility Costs . . . . .	80

Table	Page
22. Powered AGE Man-Hour Standard for an Average Production Unit . . . . .	92
23. Non-Powered AGE Man-Hour Standard for an Average Production Unit . . . . .	93
24. Corrosion Work Center Scheduling Estimates . . . . .	95
25. Corrosion Work Center Man-Hour Estimates . . . . .	97
26. Projected/Recorded Man-Hour Comparison (per calendar year) . . . . .	98
27. Dollar Savings Analysis (per calendar year) . . . . .	99
28. Airman Hourly Wage . . . . .	103

# LIST OF FIGURES

Figure	Page
1. Short-Run Average Cost Curve . . . . .	10
2. Long-Run Average Cost Curve . . . . .	10
3. Short-Run Average Cost Curves, Laundry A . . . . .	52
4. Short-Run Average Cost Curve, Auto Laundries . . . . .	57
5. Short-Run Average Cost Curves, Painting Firms . . . . .	61
6. Corrosion Work Center Workflow . . . . .	87

## CHAPTER 1

### INTRODUCTION

#### Problem Statement

Equipment damage, along with degradation or loss of performance capability, can often be traced to corrosion. Any one or all of these results of corrosion frequently represent a monetary loss to an organization owning or operating the equipment through loss of productive time and/or costs to repair or replace the damaged equipment (3:1-3; 36:1.1).

Within the United States Air Force, many maintenance work centers are required by directives such as Air Force Manual 66-1, Maintenance Management, or equipment technical manuals to perform work on equipment to control or prevent corrosion (38:1.1; 43:3.1; 44:3.1; 45:3.1). On any given Air Force base possessing aerospace ground equipment, vehicles, and munitions, one might find vehicle specialists, munitions specialists, aircraft maintenance specialists, and others inspecting, washing, waxing, wiping, sanding, and painting vehicles and equipment as a part of their daily work. Given that corrosion control is necessary, it is possible that a consolidated corrosion control work center with the primary duty of performing corrosion control maintenance

might be able to accomplish the same work at less cost than the separate maintenance work centers.

### Background

General recognition by the United States military and the American scientific community of corrosion as a significant problem can be traced to the period during World War II (16:vii). Lack of significant emphasis prior to World War II does not mean, however, that corrosion was not a problem prior to that period. Deterioration of materials and equipment due to corrosion was and is a problem dating back to the first artifact created by man. The theaters of operation in World War II, however, which encompassed virtually every extreme of climate, provided conditions which led to deterioration of equipment on a scale never experienced before by any major military organization. Accordingly, concentrated attention and effort by the United States military were focused during the World War II period upon the problem of corrosion.

A coordinated attack upon the problem of corrosion was first seen in the creation of the Army-Navy Deterioration Steering Committee under the National Defense Research Committee in the early 1940's; and in 1943, the Tropical Deterioration Information Center was established. In 1945, recognition of the usefulness of these organizations led to the creation of more permanent organizations: the Joint Army-Navy Deterioration Prevention Committee and the Prevention of Deterioration Center under contract with the

National Research Council of the National Academy of Sciences. The Department of the Air Force, upon its creation as a separate service, joined ranks with the Departments of the Army and Navy in supporting research into the prevention of corrosion (16:vii-viii).

Corrosion as a costly problem was again brought into sharp focus within the Air Force as a result of the current trend in the United States Government toward smaller defense budgets expressed as a percentage of the Gross National Product and the resulting need to reduce maintenance costs while concurrently maintaining military effectiveness and efficiency. In 1974, the Air Force established the Maintenance Posture Improvement Program (MPIP) with the declared purpose of initiating "a program to reduce maintenance manpower and materiel costs and increase effectiveness of mission support [49:1]." By Air Staff direction in 1975, the MPIP was expanded to encompass all aspects of the corrosion problem.

Tasking will include working level panels . . . to actively probe, evaluate and present recommendations on all possible means/alternatives available to promote and develop a more effective [corrosion prevention] program for the Air Force. All efforts will be focused on identifying changes and improvements that will produce reductions in corrosion damage and associated costs [39].

#### Justification

Resource Conservation.--The rising costs of manpower, materiel, and weapon systems in an era of limited defense allocations have provided a strong mandate for effective and

efficient use of resources. In 1973, General George S. Brown, then United States Air Force Chief of Staff, recognized the impact of rising costs upon defense forces:

All of us must recognize certain basic truths. First, defense costs, like costs everywhere, have been climbing steadily. Second, even if defense spending could be maintained at a fixed level in current dollar terms, there is an erosion of real purchasing power. Third, this has necessitated reduction in force size. Fourth, the reduced force structure makes it more than ever imperative to offset numerical inferiority with qualitatively superior weapon systems. But, fifth, the cost of these systems has also been climbing so rapidly that we face such alternatives as reduced quality, lesser numbers, or just not going forward at all with some programs that are needed. These factors can only degrade the effectiveness of our defense forces, unless we move in the right direction of greatly increased efficiency in the way we do business. Cost-consciousness--cost avoidance--cost reduction will have to be our way of life [6:761].

Since 1968, the peak year of defense outlays, the defense budget, in terms of constant 1974 dollars, has steadily declined (26:25). Jacques S. Gansler, Deputy Assistant Secretary of Defense, Materiel Acquisition, in a speech on 23 October 1975, stated that, although total Government and Federal spending had grown over the last five years, total defense spending, in terms of constant 1976 dollars, had actually declined \$19 billion. He further emphasized that the defense share of the Gross National Product had been reduced from 6.9 per cent to 5.8 per cent and that a similar reduction from 33.3 per cent to 26.9 per cent had occurred in the defense share of the Federal budget (41).

Although defense outlays in terms of real purchasing power have been diminishing in recent years, the costs of

maintaining a realistic and viable defense have continued to increase. Manpower costs as a percentage of total defense costs have increased from 43 per cent in 1964 to the current 1976 estimate of 53 per cent (49:7). Operational and maintenance (O&M) costs have concurrently grown in magnitude while research and development costs have remained relatively constant over the last five years. Procurement dollars, as a result, have been reduced significantly (41).

The Department of Defense is now at the point where additional force reductions cannot be made without altering the balance of forces vis-à-vis the Eastern Powers (4:8). Since the military force structure is considered to be at a minimum level, military managers need to strengthen the force structure through more efficient use of people and resources. Managers at all levels should consistently seek new and better ways to accomplish and efficiently support the mission through minimum resource consumption.

Corrosion.--Corrosion has been long recognized as a major factor in reducing the effective life span of facilities, equipment, and materiel. Shortened equipment life span, corrosion damaged equipment, and the prevention and control measures used to combat corrosion represent unrecoverable economic losses for the consuming public.

In 1970, Bosich estimated the annual economic loss in the United States as a result of corrosion to be \$20 billion (3:1). Replacement costs for automobile mufflers irreparably damaged by corrosive agents were estimated in

1973 at an annual cost of \$100 million (30:1). Similar large sums of money have been expended by industry to prevent and control corrosion. Professor Herbert H. Uhlig, Department of Metallurgy and Materials Science, Massachusetts Institute of Technology, corroborated the magnitude of the sums in a keynote address before the 1972 Tri-Service Conference on Corrosion. He stated that:

Pipeline maintenance reaches the order of many hundreds of millions of dollars annually. Protection of steels by paints requiring frequent renewal drains the economy in the order of billions of dollars annually [30:1].

The impact of corrosion is no less significant for the Air Force. The Air Force Inspection and Safety Center (AFISC), located at Norton Air Force Base, California, estimated in July 1975 that the efforts to deter aircraft corrosion and to repair aircraft damaged by the corrosion process were costing the Air Force \$1 billion annually (37:21). The magnitude of the impact on Air Force equipment is extensive both in terms of dollar cost and operational effectiveness. Recently, for example, the repair of structural damage to the wing of one series of aircraft, as a result of corrosion, cost as much as the original wing (47:13). Corrosion repair costs for the C-141 in fiscal year (FY) 1974 were approximately \$8 million, and an identical amount was projected for repair of corrosion structural damage to the B-52G series aircraft for FY 1975 (37:21).

The dollar costs illustrated above reflect unrecoverable losses due to actual corrosion damaged equipment. The

O&M costs for control and prevention of corrosion are also of considerable magnitude. In FY 1975, the Air Force spent an estimated \$500 million for corrosion inspection, treatment, and overhead costs (21). In some operational units, the corrosion control function consumed as much as one half of the unit funding for consumable supplies (47:13)

In view of the reduction of the real purchasing power of the defense budget and rising costs of resources, "an organized, coordinated effort is required to combat corrosion and reduce its effects on Air Force systems and equipment [27:21]." This effort should come through management innovation and efficient utilization of resources. A considerable amount of expertise has been channeled into corrosion research and technical and engineering studies (30; 47:14) furnishing the manager and corrosion specialist with methods for arresting the corrosion control process. The technical expertise for corrosion control and prevention on equipment at base level is adequate; the key issue is now efficient management of resources.

The Inspector General of the United States Air Force has summed up the problem quite well:

Corrosion is one major wear-out phenomenon which significantly influences the cost of ownership of Air Force systems. This problem is neither new nor unique to Air Force equipment; however, it must be faced and solved more effectively than it has been in the past. If programs are to succeed in this era of high and growing operating and support costs, managers must be aware of the long-term cost implications of corrosion, as well as interested in the prevention and solution of these problems. This problem is too important to be left solely for

corrosion engineering specialists to solve, and management must involve itself in the issues which such problems raise [47:13].

Although corrosion attacks wood, leather, cloth, plastics, and other materials in addition to metal, it is probably the corrosion of metal with which most people are familiar. Considerable time, effort, and supplies are expended daily in the Air Force washing, waxing, sanding, touching up, and repainting equipment to prevent or control corrosion. Maintenance work centers are tasked by technical directives to perform corrosion preventive actions upon equipment for which they are accountable and/or required to maintain (38:1.2). The result is that highly trained specialists in a variety of fields can be found at any given time on most Air Force bases performing corrosion preventive maintenance rather than the particular work for which they were trained.

This suggests that perhaps it might be more efficient if a single work center were available to perform all the corrosion preventive actions presently performed by various maintenance work centers. Such a work center would permit specialization in corrosion control and prevention activities and would, in effect, increase specialization in the maintenance work centers by reducing the scope of the maintenance performed by the maintenance work center specialists. At this point, one might ask why specialization would have anything to do with efficiency. The answer lies in the concept of economies of scale.

Economies of Scale.--Americans have long been familiar with the idea of economies of scale (22:162), that is, that larger firms can produce a product at less cost than smaller firms. It would appear almost an American tradition to equate "bigger" with "better." While tradition cannot be labeled absolute truth, economic theory and studies and examples from American and foreign industry (18:230,257,264) have provided a certain amount of scientific support for the idea.

Traditional economic theory teaches that, for a given firm or producer of some output, short-run costs per unit of output decrease as output increases up to some quantity of output and then begin to increase (18:226; 25:97). The term "short-run" implies that some cost factors are fixed, such as buildings or long-lived equipment (25:99). Graphically, this relationship between cost and output is shown as a "U" in Figure 1.

In the long-run, however, fixed cost factors become variable. For example, a firm may acquire larger facilities, automated machinery, production line specialists, and so forth. At this point, economies of scale enter the picture.

Economies of scale involve the argument that a larger firm has cost advantages partially or totally unavailable to a smaller firm (18:257-259). A small firm, in order to produce the same quantity of output as a large firm, may strain its plant capacity to the point of costly inefficiency. A small firm may not be able to use as much raw

Fig. 1. Short-Run Average Cost Curve

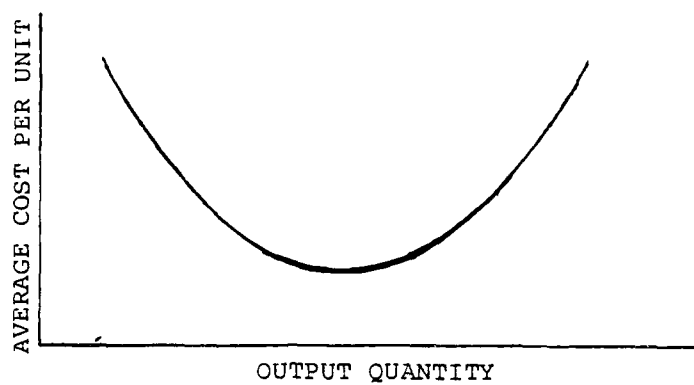
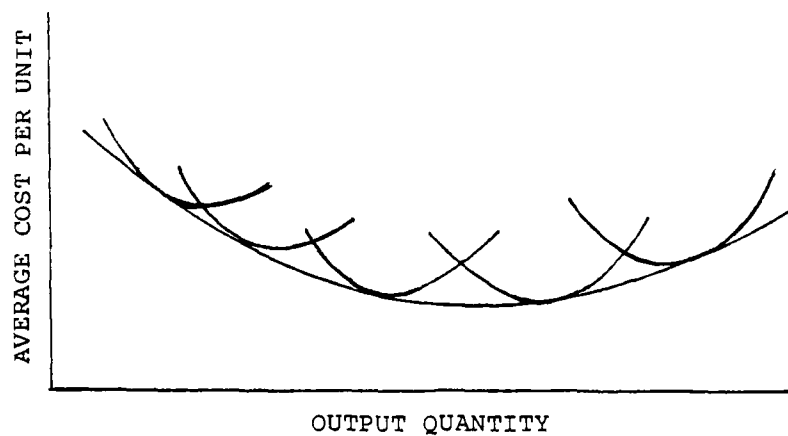


Fig. 2. Long-Run Average Cost Curve



material as a large firm and thus be unable to take advantage of bulk purchase discounts. A large firm may have large, automated machinery to mass-produce some output; but a small firm producing the same type of output might not be able to afford the high, fixed cost of such machinery. A production specialist might be able to perform some task more quickly and/or with less waste than a nonspecialist, or the specialist might be essential to some cost-saving process. Large firms could afford to employ such specialists, but a small firm might only be able to afford the services of half a specialist, a patently impossible situation. There are, of course, many other, similar examples; but these should serve to illustrate the basis of the argument for economies of scale. Eventually, however, a point is reached where the possibilities of economies of scale are exhausted; and at that point increases in scale serve only to increase average cost for any specified level of production. Figure 2 depicts this relationship.

There is no universal agreement that short-run cost curves do in actual fact follow a "U" shape (18:230,262). Some empirical studies have indicated that short-run costs are linear and that the short-run cost curves appear "L" shaped. Haynes pointed out, however, that, even if the short-run cost curves are "L" shaped, the argument for long-run economies is not invalidated (18:262).

Assuming, then, that economies of scale do exist, at least in some industries or areas of production, will

economies of scale also exist in the "industry" of corrosion prevention and control on an Air Force base? If the work centers mentioned in the previous section could be characterized as small firms with only a portion of their individual outputs in the form of corrosion prevention, then it might be possible that consolidation of the separate corrosion preventive activities could result in production of the same quantity of output at a lower cost.

#### Objective

The objective of this thesis is to investigate the possibility that a consolidated corrosion control work center could accomplish for less cost, due to economies of scale, the corrosion control activities presently accomplished in the following areas:

1. Transportation Squadron (TNS) Vehicle Maintenance Branch,
2. Field Maintenance Squadron (FMS) Aerospace Ground Equipment (AGE) Branch,
3. Organizational Maintenance Squadron (OMS) Non-Powered AGE Section, and
4. Munitions Maintenance Squadron (MMS) Equipment Maintenance Branch (or Section).

The cost effectiveness of the consolidated work center will be contrasted with the cost effectiveness of the corrosion control and prevention activities of the separate functions.

Research Question

On an Air Force base owning, operating, and maintaining motor vehicles, aerospace ground equipment, and munitions trailers and handling equipment, would corrosion control maintenance performed by a consolidated corrosion control facility be more cost effective in terms of manpower than corrosion control maintenance presently performed at the work centers owning or responsible for the particular equipment?

## CHAPTER 2

### METHODOLOGY

#### Introduction

The economic theory of long-run costs which is concerned with economies of scale gave rise to the supposition that a consolidated corrosion control work center might be more cost effective than separate work centers performing corrosion control and corrosion preventive activities in conjunction with other maintenance. The actual existence of economies of scale can be discovered or supported by the process of trial and error or by empirical studies. In the former instance, the usual approach is to estimate cost differences due to plant size and production output based upon experience in order to determine what scale of operation permits greatest output with lowest cost per unit of production. In the latter instance, generally, cost data covering a single period for several plants or organizations of different sizes producing the same product are compared to determine if increasing scale of operation results in greater output with lower cost per unit of production (18:263,267). Unfortunately, there does not appear to exist a method to test or demonstrate the existence of economies of scale when applied to a hypothetical situation. This lack means that, although it may be suggested that the

theory of economies of scale applies to the idea of a consolidated corrosion control work center, the suggestion cannot be tested by statistical or mathematical methods.

Since it is not possible to test whether a consolidated corrosion control work center would be more cost effective than the present, separate work centers, an attempt is made to draw support for this proposition through logical inference, analogy to examples in industry where economies of scale are strongly suggested, and application of some of the underlying reasons supporting the theory of economies of scale.

#### Definitions

Six technical terms used throughout this paper are defined as follows:

<u>Term</u>	<u>Meaning</u>
Action Taken Code (ATC)	A code used in the U.S. Air Force Maintenance Data Collection System which represents the description of what action or actions were taken to correct a defect or defects (40:11-1).
Corrosion	In general, deterioration of a material caused by an electrochemical reaction with the environment; usually associated with rusting of metals.
Corrosion control and corrosion preventive activities	Maintenance actions involving wiping, washing, cleaning, waxing, sanding, waterproofing, and painting.

<u>Term</u>	<u>Meaning</u>
Corrosion work centers	Work centers which perform corrosion control and corrosion preventive activities as a part of, or in addition to, other maintenance, i.e., a Transportation Squadron Vehicle Maintenance Branch, a Field Maintenance Squadron Aerospace Ground Equipment (AGE) Branch, an Organizational Maintenance Squadron Non-Powered AGE Section, and a Munitions Maintenance Squadron Equipment Maintenance Branch (or Section).
How Malfunction Code (HMC)	A code used in the U.S. Air Force Maintenance Data Collection System which represents the description of a defect or malfunction in equipment or systems (40:11-35).
Man-hour	An expression of time spent upon a job or jobs by one or more persons, the sum of which equals one hour.

#### Population

The basic reason for examining the question of a consolidated corrosion control work center is to determine if current corrosion control activities can be accomplished at a lower dollar cost. Any comparisons or arguments attempted, then, should logically be in terms of dollar cost.

To determine and compare all costs involved in a corrosion control operation for a consolidated work center with all costs of corrosion control and corrosion preventive activities of the four corrosion work centers under

consideration would be a job of such magnitude as to far exceed the scope and time constraints of this research. For example, a comparison of the cost of utilities might be desired, but the corrosion work centers perform maintenance other than corrosion control and prevention; and the problem would then arise as to how to determine what portion of the total cost of utilities for the work center under consideration should be applied to corrosion control and corrosion preventive activities. Additionally, there is doubt as to whether the total cost of utilities for any one work center could be separated from the total cost of utilities for all work centers in one general location. Another example might be the desirability of comparing the cost of transporting vehicles and AGE from the owning work center to a consolidated corrosion control work center with the cost of transportation prior to establishment of the consolidated work center. To make this comparison, the location of the consolidated work center would have to be determined. The locations of a consolidated corrosion control work center, however, would vary among Air Force bases due to the various physical layouts of the bases; and, as will be seen in the section on data collection, more than one Air Force base will be considered. Even if only one base were to be considered and a location for the consolidated work center established, the usual location of each vehicle and the distance to the vehicle maintenance work center and to the consolidated work center would have to

be determined. Again, it is anticipated that the time constraints for this research would be exceeded.

In order to avoid the difficulties described, and possibly others, consideration of costs was limited to that of capital investment costs for facilities and specialized equipment, man-hour expenditures which could be reasonably expected to have arisen from corrosion control and corrosion preventive activities, and projected man-hour expenditures for a consolidated corrosion control work center. The population, then, consisted of the man-hours expended in corrosion control and corrosion preventive maintenance incurred by the powered AGE work center, non-powered AGE work center, vehicle maintenance work center, and munitions equipment maintenance work center on an Air Force base. Bases were limited to those in the continental United States which had at least one Strategic Air Command (SAC) Bombardment Wing, one Field Maintenance Squadron, one Organizational Maintenance Squadron, one Transportation Squadron, and one Munitions Maintenance Squadron. A list of these bases is contained in Table 1.

Design to Answer the  
Research Question

Due to the inability to test the proposition that a consolidation of corrosion control and corrosion preventive activities on an Air Force base would benefit from economies of scale in the form of lower costs, an attempt is

made to suggest the probability of realizing economies of scale through consolidation. Three approaches are used.

TABLE 1  
List of Bases

Base	Base
Barksdale AFB, LA	Kincheloe AFB, MI
Beale AFB, CA	Loring AFB, ME
Blytheville AFB, AR	March AFB, CA
Carswell AFB, TX	Mather AFB, CA
Dyess AFB, TX	Minot AFB, ND
Ellsworth AFB, SD	Pease AFB, GA
Fairchild AFB, WA	Plattsburg AFB, NY
Grand Forks AFB, ND	Robins AFB, GA
Griffiss AFB, NY	Seymour Johnson AFB, NC
K. I. Sawyer AFB, MI	Wurtsmith AFB, MI

1. Arguments are advanced to demonstrate that consolidation of corrosion control and corrosion preventive activities would permit realization of some of the underlying factors of the theory of economies of scale. Haynes listed a variety of factors supporting the theory of economies of scale (18:257-258). His list appeared to apply in general to business and industry and included such factors as economies of large-scale finance and economies in sales due to increased market information and advertising. Factors such as these would be difficult, if not impossible, to equate to a corrosion work center which is not concerned with large-scale finance or sales; however, other factors listed by Haynes appeared quite applicable (see Table 2). Selection of the factors in Table 2 was a judgment decision

on the part of the researchers and was based upon perceived congruence of those factors with the corrosion control and corrosion preventive activities listed in the section on definitions.

TABLE 2  
Factors Underlying Economies of Scale

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|----|--|
| A. | Practicality of employing specialists.   |
| B. | Practicality of purchasing large, specialized machines or equipment due to volume of work. |
| C. | Ability to use production line or continuous process methods due to volume of input.       |
| D. | Ability to stabilize workload and workflow due to volume of input.                         |
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2. Two types of businesses or firms which perform corrosion control or corrosion preventive activities as a service, either exclusively or as one of a range of services, were identified based upon the similarity of their service(s) to the corrosion control and corrosion preventive activities of corrosion work centers on an Air Force base. Identification of the types of businesses or firms was a judgment decision on the part of the researchers. The two types are auto laundries and auto painting shops. A sample of convenience of the businesses or firms was selected. The data obtained are examined to determine whether economies of scale appear to exist, and parallels are drawn wherever possible to Air Force corrosion work

centers. Examination consists of a comparison of monthly average cost by volume plotted for each firm in the sample.

3. A manpower model of a consolidated corrosion control work center for the classes of equipment considered in this research was constructed, and its projected man-hour expenditure is compared with the total sum of the average man-hour expenditures of the corrosion work centers in the sample. The model was constructed as follows:

a. The heart of the model is a scheduled workflow. Into this schedule, three classes of equipment were input: powered AGE, non-powered AGE,<sup>1</sup> and motorized general purpose vehicles. Each class of equipment in the scheduling function is represented by a theoretical average unit.

b. Two classes of jobs are processed by the model: complete corrosion rehabilitation and localized corrosion control and prevention.

c. Units of work and corresponding job standards were developed by the researchers and incorporated into the model.

d. The scheduled workflow is a composite of complete corrosion rehabilitation and localized corrosion actions. The assumptions driving the schedule of work accomplished were developed by the researchers.

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<sup>1</sup>The equipment maintained by the Equipment Maintenance Branch of the Munitions Maintenance Squadron was classified as non-powered AGE for treatment in the manpower model.

### Data Collection

The quantity of vehicles, powered and non-powered AGE, and munitions trailers and munitions handling equipment (MHE) possessed and/or maintained by the corrosion work centers in the sample was obtained from each work center.

Man-hours expended by each corrosion work center in the sample except for the vehicle maintenance work centers were extracted from two sources:

1. The Maintenance Data Collection (MDC) System (LOG-MMO(AR)7142 data tapes) at Headquarters Air Force Logistics Command (AFLC) and
2. The production analysis staff function for the Deputy Commander for Maintenance (DCM) at each base identified in the sample plan.

Data for corrosion control and corrosion preventive activities during Calendar Year (CY) 1975 were collected in the form of the number of man-hours expended and units supported by the work centers under consideration. Since the corrosion work centers performed maintenance activities other than corrosion control and prevention, it was necessary to establish controls to insure only data relating to corrosion control and prevention were collected.

It is the assumption of the researchers based upon observation that not all corrosion control actions are specifically recognized or identified as such. Many such actions are often perceived as merely cosmetic or good housekeeping actions. Accordingly, corrosion control actions were identified by matching selected How Malfunction

Codes (HMC) with selected Action Taken Codes (ATC) for each item of equipment upon which work was performed. For example, the man-hours expended by an AGE work center upon an air compressor wiring harness with an HMC meaning "nicked" and an ATC meaning "replaced" would be rejected as not being corrosion maintenance; on the other hand, the man-hours expended upon an air compressor with an HMC meaning "nicked" and an ATC meaning "repaired" would be assumed to be corrosion in the form of spot painting and would be accepted as a datum. Corrosion preventive actions are linked to man-hours in the same manner. For example, the man-hours used by an AGE work center in cleaning or washing a BT-400 heater might be linked with an HMC of 230 (dirty) and an ATC of V (cleaned). This maintenance action would then be defined as corrosion prevention and accepted as a datum. The selected HMCs are listed in Table 3, and the selected ATCs are listed in Table 4.

The MDC data bank at Headquarters AFLC does not include General Support Code (GSC) 02000 man-hour expenditures. General Support Code 02000 includes corrosion prevention data and is defined as follows:

Aircraft cleaning, includes washing,<sup>2</sup> decontamination, snow and ice removal, frost, vacuuming, wiping, polishing, cleaning and treating of equipment to prevent corrosion. NOTE: Do not use code for treating corroded parts [50:XII-004].

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<sup>2</sup>Emphasis by underlining is provided by researchers.

The production analysis work center at each sample base was contacted via telephone by the researchers and requested to provide CY 1975 GSC 02000 data for the corrosion control work centers identified in the sampling plan.

TABLE 3  
How Malfunction Codes

Code	Meaning
910	Chipped
170	Corroded, mild to moderate
667	Corroded, severe
116	Cut
846	Delaminated
117	Deteriorated
230	Dirty, contaminated, or saturated by foreign material
425	Nicked
520	Pitted
865	Protective coating, sealant defective
935	Scored or scratched

TABLE 4  
Action Taken Codes

Code	Meaning	Notes
F	Repair	Not to be used for "on equipment" work if another code applies. When it is used in shop environment, this code will denote repair as a separate unit of work after a bench check. Shop repair includes cleaning.
V	Clean	Includes acid bath, sand blast, and degrease.
Z	Corrosion repair	Includes cleaning, priming, and painting of equipment which is already corroded.

Man-hours expended by vehicle maintenance work centers are not available through the Maintenance Data Collection System. Man-hours expended for corrosion maintenance by the vehicle maintenance work centers in the sample were obtained by direct communication with the Reports and Analysis Sections of the respective transportation squadrons.

The validity of the data on man-hours expended is dependent upon the ability of the controls to isolate corrosion maintenance man-hours. It is assumed that some data will be included which should be excluded and that other data will be excluded which should be included due to the inability of the controls to detect inconsistencies by individual workers in coding and recording like maintenance actions. Accordingly, the data on man-hours is summed under the assumption that the overall effect of invalid data included and valid data excluded is approximately zero. The quantity of vehicles, powered and non-powered AGE, and munitions trailers and MHE is averaged in order to establish a theoretical average pool of equipment upon which to base a schedule for flowing equipment through the manpower model.

The data on average cost and quantity of output for the selected firms or businesses were obtained directly from the firms or businesses in the sample.

#### Sample Plan

Barksdale AFB, Dyess AFB, Ellsworth AFB, Pease AFB, and Robins AFB were randomly selected as the sample bases

using the Air Force Institute of Technology (AFIT), School of Systems and Logistics (SLG) Computer Program, AF.LIB/RNDSMPL (1:6-29).

Five auto laundries and three automotive paint shops were chosen for comparison with corrosion work centers. These firms were selected from the 1976 issue of the Ohio Bell Telephone Directory for Dayton, Ohio, and Vicinity. The researchers deliberately chose firm size and output such that the data would permit examination of economies of scale. The selection was a sample of convenience and was made from those firms located within the vicinity of Wright-Patterson Air Force Base, Ohio.

#### Assumptions

1. The underlying factors of the theory of economies of scale listed in Table 2 are valid and can be applied to U.S. Air Force corrosion work centers.
2. The controls established for isolating data relating to corrosion control and corrosion preventive activities are generally effective.
3. Inconsistencies in coding and recording data will result in the collection of some invalid data and the omission of some valid data.
4. Averaging the data will tend to reduce the net effect of including invalid data and excluding valid data toward zero.

Limitations

1. Results obtained cannot be tested, and the research question cannot be proven conclusively except by actual experimentation with a consolidated corrosion control work center.
2. The physical location and the management structure of a consolidated corrosion control work center were not considered.

## CHAPTER 3

### LOGICAL ECONOMIES

#### Work Center Primary Function

It was earlier stated that corrosion work centers perform corrosion preventive activities as a part of or in addition to their primary functions. In the next few sections, the primary functions of these corrosion work centers are examined to see what it is they do and why or how corrosion preventive activities might logically be a part of their primary functions. Air Force Manual (AFM) 39-1, Airman Classification Manual, which describes the duties and responsibilities of airmen by Air Force Specialty Code (AFSC), was used as the basic source in arriving at a description of the primary functions of corrosion work centers. In two cases, however, it was also found necessary to draw upon the maintenance experience of the researchers due to the fact that there exists no specific AFSC for the functions performed. It is likely that many who are unfamiliar with the particular work centers in question will find the descriptions almost intuitively obvious from their own experience with similar work centers, either in the military or in civilian business and industry.

FMS AGE Branch.--A Field Maintenance Squadron (FMS) Aerospace Ground Equipment (AGE) Branch is primarily concerned with maintenance of powered equipment used in direct support of aircraft, systems, or subsystems (33:A21.25). It also provides servicing of the equipment with fuel, oil, etc., and delivery and pickup of the equipment to and from users. The equipment consists of such things as

motor and engine driven generator sets, air compressors, hydraulic-pneumatic sets, air conditioners, heaters, exhaust and cooling equipment, and test stands [33:A21.27].

Maintenance consists of actions such as periodic and special inspections, test operating, troubleshooting, repair, overhaul, assembly replacement, adjusting, and modifying equipment. AGE mechanics receive on-the-job training in

principles of electrical, electronics, heating, refrigeration, pneumatics, hydraulics, internal combustion engines and small gas turbines as applied to aerospace ground equipment, and use of applicable technical publications, blueprints, diagrams, material, and maintenance control procedures . . . . Completion of a basic aerospace ground equipment maintenance course is desirable [33:A27.27]

and is the rule rather than the exception in the case of military personnel.

OMS Non-Powered AGE Section.--The personnel assigned to an Organizational Maintenance Squadron (OMS) Non-Powered AGE Section are, as a rule, aircraft maintenance technicians or specialists (AFSC 431X1).<sup>1</sup> For this reason, AFM 39-1

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<sup>1</sup>The X represents the number 3, 5, or 7 which is a skill level indicator.

is not extremely helpful in determining the work performed by the Non-Powered AGE Section as the job descriptions in the manual concentrate upon the aircraft maintenance aspect of the duties of the aircraft maintenance specialist and technician. Some information, however, can be extracted from the manual.

Air Force aircraft maintenance personnel are required to operate, inspect, repair, maintain, troubleshoot, service, and modify aircraft and related aerospace equipment, including non-powered ground equipment (33:A22.9,A22.11). From this job description, it may be deduced that the Non-Powered AGE Section is, as a minimum, responsible for the inspection, repair, maintenance, troubleshooting, servicing, and modification of non-powered AGE. Other responsibilities include maintenance of equipment records and maintenance data documentation and reporting (33:A22.9). The maintenance experience of the researchers confirms the deduction. Examples of non-powered ground equipment are maintenance stands, jacks, and towing units (33:A22.9).

MMS Equipment Maintenance Branch.--The personnel assigned to a Munitions Maintenance Squadron (MMS) Equipment Maintenance Branch (or Section) are generally munitions maintenance specialists. Here, again, AFM 39-1 is not very helpful in determining the work performed by the branch; and much reliance is placed upon the maintenance experience of one of the researchers who is a munitions officer. The job descriptions in AFM 39-1 are primarily

centered around activities involving inspection, maintenance, storage, build up, and delivery of munitions (33:A24.5,A24.7); but, as in the case of the OMS Non-Powered AGE Section, some information can be gleaned from the manual.

Munitions Maintenance personnel are responsible for the maintenance and reconditioning of handling equipment. Reconditioning consists of straightening, sanding, cleaning, and replacing defective or damaged parts (33:A24.5, A24.7). With the exception of certain specialized items of equipment maintained by the owning work center, the Equipment Maintenance Branch is responsible for the maintenance and reconditioning of handling equipment (45:7.1). Of primary interest to this research are the large items of handling equipment such as bomb trailers. Maintenance of bomb trailers includes inspection, repair, adjustment, replacement, and modification of components such as tires, brake assemblies, hydraulic assemblies, and electrical systems.

TNS Vehicle Maintenance Branch.--A Transportation Squadron (TNS) Vehicle Maintenance Branch is primarily concerned with maintenance of specialized and general purpose vehicles and base vehicle equipment (33:A25.2). Maintenance consists of actions such as inspecting, testing, troubleshooting, and analyzing

the vehicle engine mechanical systems; crank-case ventilating systems; exhaust emission and

anti-pollution systems; lubricating, cooling, air conditioning, and exhaust systems; engine electrical systems; engine fuel-air system; and power train, brakes, steering and suspension systems [33:A25.13].

Maintenance also includes inspection and repair of vehicle body and frame damage, entailing straightening, welding, cleaning, painting, cutting, sanding, and grinding (33:A25.15). Vehicle maintenance and body mechanics receive on-the-job training; and basic maintenance courses are desirable, but not required (33:A25.14,A25.16).

Corrosion Control/  
Prevention Requirement

Requirement.--Technical Order (T. O.) 1-1-2, Corrosion Prevention and Control, states that fighting corrosion is the responsibility of all workers, supervisors, and managers (38:1.1). Technical orders for specific equipment include instructions for corrosion prevention and control (38:1.2). Maintenance supervisors are specifically enjoined to insure a corrosion control program is maintained within their spheres of responsibility (43:3.1;44:3.1;45:3.1). Job descriptions for several AFSCs make specific reference to corrosion control and prevention responsibilities (33:A21.25,A22.9,A25.13, and others). There are numerous other examples; but those given bear witness to the fact that the Air Force has directly and specifically charged its workers, supervisors, and managers to concern themselves with corrosion control and prevention.

Execution.--The basic methods employed by corrosion work centers in combating corrosion are cleaning, washing, and painting (36:1.1;34:1.1). Facilities and equipment for cleaning, washing, and painting vary by work center and by base, ranging from a water hose and brush to an automated car laundry and from an aerosol paint spray can to a painting booth. It is suggested that, in the majority of cases, the facilities and equipment available to corrosion work centers for cleaning, washing, and painting are minimal. Researcher experience and contact with the bases in the sample would seem to support that suggestion (5;12;19;29;53); and, too, the suggestion would seem reasonable in light of the fact that corrosion control and prevention activities constitute but a fraction of the maintenance responsibilities of corrosion work centers as previously described. It is suggested, then, that performance of corrosion activities by corrosion work centers is accomplished manually and in small quantities over a period of time.

#### Economies of Scale

In Table 2 on page 20 are listed some of the factors underlying economies of scale. The common denominator behind all of the listed factors would seem to be volume of production. The idea would appear almost intuitively obvious. An artist spends many hours, days, and weeks producing a single painting. The volume in this instance is low, and the price (or cost to the consumer) is frequently high. On the other hand, a reproduction of a masterpiece can be purchased for a

relatively low price. In this case, machinery and mass production techniques are used to produce high volume in a short period of time.

It has been hypothesized that corrosion work centers individually produce a low volume of corrosion control and prevention output. It has been suggested that this work is accomplished primarily with limited facilities and equipment. If this be the case, then corrosion work centers might be considered as small "firms" producing the same output: corrosion control and prevention. Because of their small size (or scale), they are unable to afford specialized, mass production equipment; and they are not able to "hire" specialists. In addition, some slack time in the form of time required for personnel relocation and setup time occurs each time a worker is moved from maintenance production to corrosion production and vice versa. If the short-run average cost curves of these small "firms" were to be plotted on the same graph, their relationship with one another would appear similar to the relationship of the first two short-run average cost curves from the left in Figure 2. On the other hand, combining the corrosion control and prevention responsibilities of the corrosion work centers and placing them with a single work center dedicated to the sole purpose of corrosion control and prevention might result in a volume of work sufficient to justify special facilities and equipment. This single work center might be viewed as a large firm producing

corrosion control and prevention. Because of its large scale, it would be able to afford large, specialized equipment such as automatic vehicle and equipment washers; high capacity, multiple paint sprayers; and dryers.

High volume and facility scale would make feasible a product layout facility which would have the effect of stabilizing workflow through production line techniques, minimizing slack time, and allowing specialization of labor (8:111,119). This large "firm," a consolidated corrosion control and prevention work center, would be able to produce the same volume of output as the smaller "firms" combined and at a lower average cost per unit through its ability to purchase specialized machinery, "hire" specialists, utilize production line techniques, and stabilize workflow. The short-run average cost curve of this large firm, compared with the short-run average cost curves of the smaller firms, would be similar to the relationship of the third short-run average cost curve in Figure 2 with the two higher curves to the left.

#### Summary

Corrosion work centers have a multitude of maintenance functions, one of which is corrosion control and prevention. It is possible, and indeed seems likely, that corrosion maintenance produced by these work centers is low in volume and relatively high in average per unit cost in terms, at least, of man-hours. Consolidation of corrosion

maintenance responsibilities under a single, specialized work center would possibly create sufficient volume of work to justify specialization of personnel; use of specialized equipment, machinery, and facilities; and product layout techniques and principles. The result of such a consolidation could logically be expected to be a higher output at a lower average cost per unit.

## CHAPTER 4

### CIVILIAN INDUSTRY DATA

#### Introduction

The theory of economies of scale, discussed in Chapter 1, suggested that a consolidated corrosion control facility might be able to produce, at a lower average cost per unit, the same or greater output as the various corrosion work centers combined. Two industries, auto laundries and auto painting, were selected for the similarity of their product to the product of the corrosion work centers. Auto laundries, as one might expect, wash vehicles; and auto painting shops paint vehicles, either partially, such as a fender from which a dent was removed, or completely. Corrosion work centers wash, clean, and paint vehicles, aerospace ground equipment, and munitions trailers. If it could be shown that various sizes of firms or businesses within the auto laundry industry and the auto painting industry appear to demonstrate the existence of economies of scale, then it might be reasonable to

suppose that economies of scale could also exist in the corrosion control and prevention "industry" on an Air Force Base.

In order to examine the two industries for economies of scale, CY 1975 cost data for five auto laundries and three auto painting firms were obtained, and short-run average cost curves were plotted. The curves were individually examined for conformance to the theoretical "U" shaped curve shown in Figure 1, and the curves were collectively compared, grouped by industry, to see if they exhibited different average costs per unit for different scales of operation. The data are considered proprietary information by some of the firms, and therefore all firms are referred to throughout this paper by alphabetical letter.

#### Data Presentation

Data Collection.--Data for the sample firms were obtained directly from business owners, firm presidents, and, in two instances of firms with more than one output, functional managers. A structured interview (see Appendix A) was used to insure uniformity of data input. Data requested were (1) the quantity of vehicles processed by

month in CY 1975, (2) the cost of sales by month, (3) operating expenses by month, and (4) fixed costs. Figures for operating expenses were totals which included items such as wages and office salaries, advertising, customer property damage, equipment base, rent, maintenance and repair, employee compensation, group insurance, insurance, accounting and legal fees, taxes and licenses, office expenses, payroll taxes, telephone charges, uniforms and laundry, utilities, interest and bank charges, etc. All of the firms in the sample included the cost of sales in operating expenses. Data for fixed costs were in the form of equipment costs and capital improvement or lease costs. In the case of the three auto painting firms, fixed costs of owned equipment and buildings were provided in the form of replacement costs and in the form of lease costs for non-owned buildings. The auto laundries provided purchase costs for equipment, capital improvement costs for facilities, and the effective year of each.

Data Derivations. --In order to plot short-run average cost curves for the sample firms, it was necessary to calculate average cost per unit output per month for each firm. Average cost per unit per month was

calculated by dividing total cost per month by the volume of output for the month (25:124). Total cost per month was simply the sum of variable cost and fixed cost (25:122).

The variable costs per month used in the preceding equations were obtained directly from the data collected, i.e., operating expenses by month. Fixed costs were treated somewhat differently.

The fixed costs of a firm are, in general, those which do not vary with different levels of production in the short run. Examples are the cost of equipment, buildings, real estate, etc. These costs represent sunk costs and are, as a rule, recovered over the life of the facility or equipment by making a periodic charge (depreciation) to the cost of production (25:126). In the case of the auto painting firms, fixed costs were obtained from two firms in the form of equipment replacement costs and lease costs and from the third firm in the form of building and equipment replacement costs, thus providing a common base for comparison. No attempt was made to determine a depreciation figure for the equipment replacement costs. Rather, in each case, the full replacement cost was added to the monthly lease in two cases and to the monthly depreciation

cost<sup>1</sup> of the owned facility in the third case. The resulting fixed costs were then added to the corresponding variable costs for each month to yield total costs per month for the three auto painting firms. The physical implication of this mathematical treatment of equipment replacement costs is that the three firms purchased new equipment each month which, of course, was certainly not the case; however, our purpose was merely to examine the relationship of the resulting short-run average cost curves (higher or lower on the graph with respect to scale), not actual cost differences. The treatment of the equipment replacement costs resulted in distorted magnitudes; but due to the mathematical properties of inequalities, the treatment did not change the relationship of the curves.

The fixed costs of the auto laundries were treated in a manner similar to that of the auto painting firms, the single difference lying in the treatment of facility costs. Facility costs for the auto laundries were provided in terms of capital improvement costs. In this case, equipment replacement costs were simply added to

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<sup>1</sup>The monthly depreciation of the facility replacement cost was calculated from a 10 percent depreciation factor over a period of 25 years (25:462).

capital improvement costs to obtain fixed costs; and, as in the case of the auto painting firms, the fixed cost for each auto laundry was added to the variable cost for each month to obtain a total cost. Here, again, curve relationships, but not magnitudes, were maintained.

Two additional mathematical manipulations of fixed cost data were found necessary. Facility and capital investment costs which were incurred during different years would not be comparable due to inflation of the United States dollar. Accordingly, the present value (25:377) of all facility and capital investment costs for the five auto laundries was calculated in order to obtain a common ground for curve comparison. Appropriate compound amount factors taken from a table of 10 percent discrete interest factors (25:462) were used to calculate present value. The final manipulation of fixed cost data involved two of the auto painting firms which produced outputs other than painting. For these two firms, an estimate was obtained during the interviews as to what portion of the shop facility and equipment was used for painting; and these factors were used to reduce the fixed costs of each firm to figures representing fixed costs associated only with painting output.

Data Tables.--Tables 5 through 9 depict data obtained from the sample auto car laundries; and Tables 10, 11, and 12 contain the data from the sample auto painting firms. The second and third columns contain data collected from the firms, and the fourth and fifth columns contain figures calculated from collected data as discussed in the previous section.

#### Curve Comparison

The points corresponding to average cost per unit and volume of output were plotted for each month for each firm. Figure 3 shows the points plotted for auto laundry A. As can be seen in the figure, the points appear to suggest a parabola (described by the solid and dash arcs) which would agree with the theoretical curve shown in Figure 1, Chapter 1. Unfortunately, the data did not yields points indicating increasing average cost per unit with increasing output; and it is possible, though extremely unlikely, that average cost per unit might again begin to decrease with increased output. The plotted points for the remaining seven firms demonstrated exactly the same behavior. All of the sample auto laundries were capable of processing at least 60 vehicles per hour; and all were

TABLE 5  
Auto Laundry A

Month	Vehicle Output	Variable Cost	Fixed Cost	Average Cost Per Unit
1975				
May	7,021	\$ 5,412	\$144,203*	\$21.31
Jun	6,079	4,785		24.50
Jul	5,822	5,402		25.70
Aug	5,670	5,971		26.49
Sep	4,176	4,837		35.69
Oct	5,205	6,715		28.99
Nov	5,401	9,630		28.48
Dec	5,794	4,037		25.59
1976				
Jan	5,972	\$ 4,155	\$144,203*	\$24.84
Feb	9,648	6,744		15.65
Mar	6,013	8,449		25.39

\*Amount remains the same for all months.

TABLE 6  
Auto Laundry B

Month	Vehicle Output	Variable Cost	Fixed Cost	Average Cost Per Unit
1975				
May	5,021	\$ 3,917	\$176,351*	\$35.90
Jun	4,541	4,361		39.80
Jul	5,430	4,415		33.29
Aug	4,445	4,700		40.73
Sep	3,251	3,995		55.47
Oct	5,334	5,785		34.15
Nov	2,670	5,226		68.00
Dec	5,183	4,194		34.83
1976				
Jan	4,502	\$ 4,244	\$176,351*	\$40.11
Feb	5,087	4,572		35.56
Mar	4,988	4,335		36.22
Apr	6,124	5,086		29.63

\*Amount remains the same for all months.

TABLE 7  
Auto Laundry C

Month	Vehicle Output	Variable Cost	Fixed Cost	Average Cost Per Unit
1975				
May	10,102	\$ 7,951	\$221,415*	\$22.71
Jun	7,923	6,316		28.74
Jul	7,489	11,397		31.09
Aug	5,936	7,239		38.52
Sep	5,192	6,145		43.83
Oct	7,382	6,207		30.83
Nov	7,531	0,486		30.66
Dec	8,418	7,707		27.22
1976				
Jan	8,943	\$ 8,811	\$221,415*	\$25.74
Feb	11,972	7,359		19.11
Mar	9,896	10,388		23.92
Apr	9,865	11,585		23.62

\*Amount remains the same for all months.

TABLE 8  
Auto Laundry D

Month	Vehicle Output	Variable Cost	Fixed Cost	Average Cost Per Unit
1975				
May	13,083	\$ 9,725	\$304,221*	\$24.00
Jun	10,916	7,319		28.53
Jul	9,649	10,893		32.66
Aug	10,064	8,661		31.09
Sep	8,723	7,561		35.74
Oct	10,439	7,099		29.82
Nov	10,821	9,989		29.04
Dec	11,338	9,770		27.69
1976				
Jan	12,165	\$ 8,823	\$304,221*	\$25.73
Feb	6,172	5,986		50.26
Mar	12,870	10,189		24.42
Apr	13,343	12,695		23.75

\*Amount remains the same for all months.

TABLE 9  
Auto Laundry E

Month	Vehicle Output	Variable Cost	Fixed Cost	Average Cost Per Unit
1975				
May	5,167	\$ 5,149	\$202,541*	\$40.20
Jun	4,080	4,856		50.83
Jul	4,420	6,145		47.21
Aug	4,920	5,959		42.37
Sep	3,917	4,882		52.95
Oct.	4,160	5,184		49.93
Nov	4,417	4,947		46.97
Dec	5,063	6,241		41.23
1976				
Jan	6,083	\$ 6,588	\$202,541*	34.38
Feb	6,167	5,987		33.81
Mar	4,750	6,956		44.10
Apr	5,250	5,783		39.68

\*Amount remains the same for all months.

TABLE 10  
Auto Painting Firm A

Month	Vehicle Output	Variable Cost	Fixed Cost	Average Cost Per Unit
1975				
Jan	12	\$1,049.88	\$2,000*	\$254.16
Feb	9	721.76		302.42
Mar	5	586.53		517.31
Apr	11	808.25		255.30
May	12	840.00		236.67
Jun	11	934.23		266.75
Jul	12	1,258.07		271.51
Aug	11	1,061.31		278.30
Sep	8	865.10		358.14
Oct	12	1,182.50		265.21
Nov	11	1,179.19		289.02
Dec	12	1,130.43		260.87

\*Amount remains the same for all months.

TABLE 11  
Auto Painting Firm B

Month	Vehicle Output	Variable Cost	Fixed Cost	Average Cost Per Unit
1975				
Jan	312	\$18,414	\$86,469.33*	\$ 844
Feb	347	18,995		761
Mar	227	17,305		1,156
Apr	328	14,612		792
May	246	14,1973		1,054
Jun	328	19,851		807
Jul	326	16,476		802
Aug	256	19,111		1,032
Sep	327	14,717		794
Oct	328	19,160		805
Nov	362	19,481		731
Dec	308	19,461		859

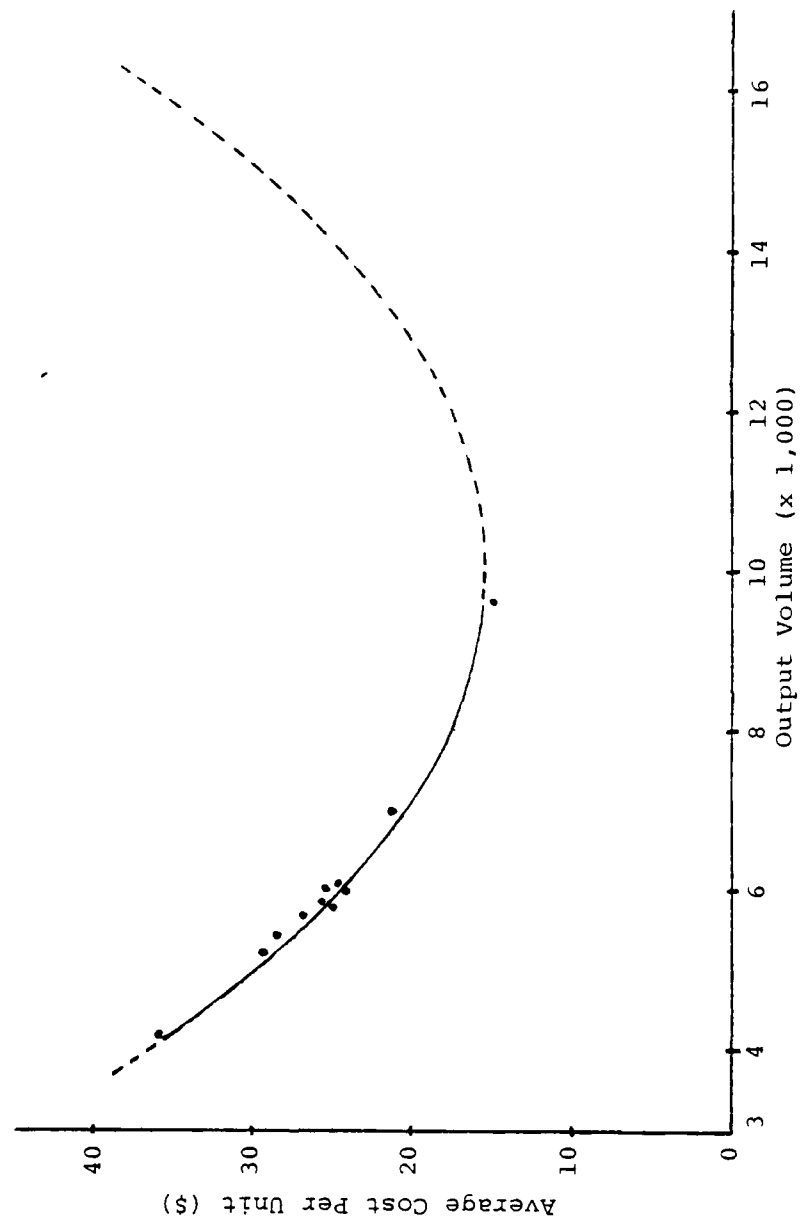
\*Amount remains the same for all months.

TABLE 12  
Auto Painting Firm C

Month	Vehicle Output	Variables Cost	Fixed Cost	Average Cost Per Unit
1975				
Jan	116	\$10,000	\$61,250*	\$ 614.22
Feb	131	12,500		562.98
Mar	201	13,232		371.01
Apr	238	14,200		317.02
May	269	15,802		286.44
Jun	202	15,800		381.44
Jul	263	15,800		292.97
Aug	211	21,000		389.81
Sep	228	61,250		360.75
Oct	197	21,000		417.51
Nov	142	17,000		551.06
Dec	50	7,800		1,381.00

\*Amount remains the same for all months.

Fig. 3. Short-Run Average Cost Curve, Laundry A



open for business 18 hours a day, seven days per week. Simple multiplication showed that the auto laundries would be capable of the increased output necessary to permit extrapolation of their short-run average cost curves.

A second degree curve was fitted to the data points of each firm by multiple linear regression. The regression was accomplished using the Air Force Institute of Technology (AFIT), School of Systems and Logistics (SLG) Computer Program, SL.LIB/MLREG (1:6.52). Since multiple linear regression was used to fit a second degree curve, it was necessary to code the general quadratic equation in the following manner:

$$\text{Let } x = x_1 \text{ and } x^2 = x_2$$

$$\text{Then } y = a + bx + cx^2$$

$$\text{Becomes } y = a + bx_1 + cx_2$$

Where  $y$  represents the average cost per unit,  $x_1$  represents the volume of output and  $x_2$  represents simply the square of the volume of output. To obtain the values of  $a$ ,  $b$ , and  $c$ , it was only necessary to enter the values for average cost per unit, the corresponding values for output, and the squares of the values for output. Table 13 lists the quadratic equations derived for the short-run average cost curves of the firms in the sample.

TABLE 13

## Curve Equations

Firm	Curve Equation	R <sup>2</sup>	ΔR <sup>2</sup>
<u>Laundry</u>			
A	$(5.8858537 \times 10^{-7})X^2 - (1.17620391 \times 10^{-2})X + 74.409633 = Y$	.9958884	.003374
B	$(2.4428167 \times 10^{-6})X^2 - (3.2112321 \times 10^{-2})X + 135.39804 = Y$	.9969726	.0027429
C	$(4.0769958 \times 10^{-7})X^2 - (1.0468411 \times 10^{-2})X + 86.569228 = Y$	.9956289	.0035363
D	$(3.7101991 \times 10^{-7})X^2 - (1.0889484 \times 10^{-2})X + 103.13818 = Y$	.9987527	.0009333
E	$(1.5945539 \times 10^{-6})X^2 - (2.4487662 \times 10^{-2})X + 124.2623 = Y$	.9996460	.0000401
<u>Paint Shop</u>			
A	$4.52779X^2 - 113.83264X + 973.11574 = Y$	.9747662	.0002755
B	$(4.32076 \times 10^{-3})X^3 - 3.7420499X + 1080.1571 = Y$	.9831002	.0000003
C	$(2.891449 \times 10^{-2})X^2 - 13.634914X + 1920.5211 = Y$	.9605626	.0350015

The computer program, in addition to calculating the values of  $a$ ,  $b$ , and  $c$ , also calculated the coefficient of determination ( $R^2$ ) which is an indicator of how well the resulting equation fits the data points (54:350). Values of  $R^2$  approaching one indicate a good fit. In order to test the unlikely possibility that average cost per unit might begin to decrease instead of increase beyond the last plotted data point of the firms, a third degree curve which would permit such behavior was also fitted to the data for each firm using the same computer program. A small increase in the value of  $R^2$  would indicate that the increase in explanatory power of the resulting cubic equation due to the addition variable,  $x^3$ , was small or insignificant. Table 13 lists the coefficients of determination ( $R^2$ s) for the derived quadratic equations and the increase in  $R^2$ s due to the addition of an  $x^3$  term. In all cases, it was noted that the  $R^2$  value was very high indicating excellent curve fit and that the increase in  $R^2$  due to the addition of an  $x^3$  variable was extremely small indicating negligible significance. All of this strongly supported the a priori assumption that the short-run average cost curves of the firms in the sample would follow economic theory.

### Analysis

As stated earlier in the chapter, variable/fixed cost and volume data were gathered from commercial auto laundries and auto painting firms. The objective was to demonstrate, if possible, that economies of scale might exist in industries whose functions are similar to the tasks to be performed in the corrosion work centers. The auto laundries are examined first.

The short-run average cost curves of the five auto laundry firms are depicted graphically in Figure 4. The curves appear to be randomly distributed on the graph which would initially suggest that economies of scale do not exist in the exterior car wash industry. It is possible, however, that the position of the curves in Figure 4 is a function of volume and capital investment rather than scale. Table 14 lists the capital investment factors for the auto laundries contained in the sample. Also listed in the Table is the wash tunnel size of each auto laundry, capital improvement (construction) costs, equipment costs, year of purchase for capital improvements and equipment, and the manufacturer of the exterior car wash system.

As noted earlier, capital costs consisted of capital improvements and equipment. Differences of up to 74

Fig. 4. Short-Run Average Cost Curves, Auto Laundries

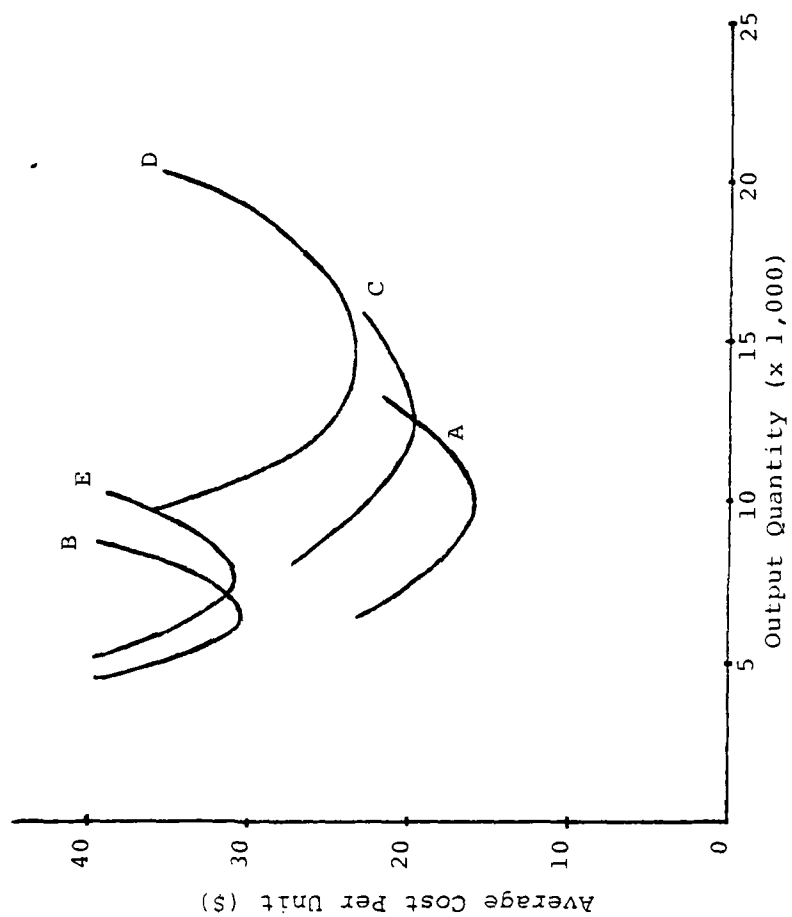


TABLE 14  
Auto Laundry Capital Investment

Auto Laundry	Tunnel Size	Capital Improvements	Equipment	Year Purchased	Equipment Manufacturer
A	40x20	\$ 80,000	\$ 39,176*	1974	Manufacturer A
A	40x20	106,269	26,226	1973	Manufacturer A
C	60x20	130,000	36,353	1973	Manufacturer A
D	60x20	154,932	52,855	1972	Manufacturer B
E	60x20	113,847	40,036	1973	Manufacturer A

\*Includes water reclamation unit.

percent in capital improvement and equipment costs are noted among the five auto laundries. It seems probable that differences in construction costs could be accounted for by differences in tunnel size, commercial location, and the bid let to the building contractor. Similarly, differences in equipment costs might be a function of the year of purchase, discounts offered, and, in one case, manufacturer.

All of the auto laundries included in the sample process vehicles with a common equipment base consisting of a high pressure water system, a hot wax/water mixture, mechanized brushes for scrubbing, an air blower, and a conveyor. It would appear, then, that economies of scale could not be expected in the sample of the auto laundry industry since essentially the same scale of fixed productive plant was being utilized by all five firms.

Although the data from the auto laundries do not indicate the existence of economies of scale for the auto laundry industry, it does not necessarily follow that economies of scale do not exist. It is the belief of the authors, based upon their search for auto laundry industry data, that the level of automation, specialization of

effort, and production line methods of the auto laundry firms in the Dayton area (in other words, scale) have resulted in cost economies sufficient to eliminate smaller scale forms of competition such as the local service station offering a car wash by hand. On the other hand, it appears that demand has not saturated the production capability of auto laundry firms in the Dayton area and, consequently, the firms have not been forced through competition to increase their present scale of production such as through an increase in the number of servers.

Although economies of scale were not seen in the auto laundry industry, the short-run average cost curves for the sample firms in the auto painting industry do suggest economies of scale. The curves are illustrated in Figure 5. The relationship between the curves of Firms B and C as shown in Figure 5 indicates that economies of scale might exist provided that the scale of Firm B is larger than that of Firm C. The curves indicate that Firm B is able to produce a larger volume of a product at less cost than Firm C. From Table 15, Column 4, it can be seen that the productive plant of Firm B is double that of Firm C. It is noted that Firm C is labor intensive and uses 77 percent more floor space than Firm B but produces a

Fig. 5. Short-Run Average Cost Curves, Painting Firms

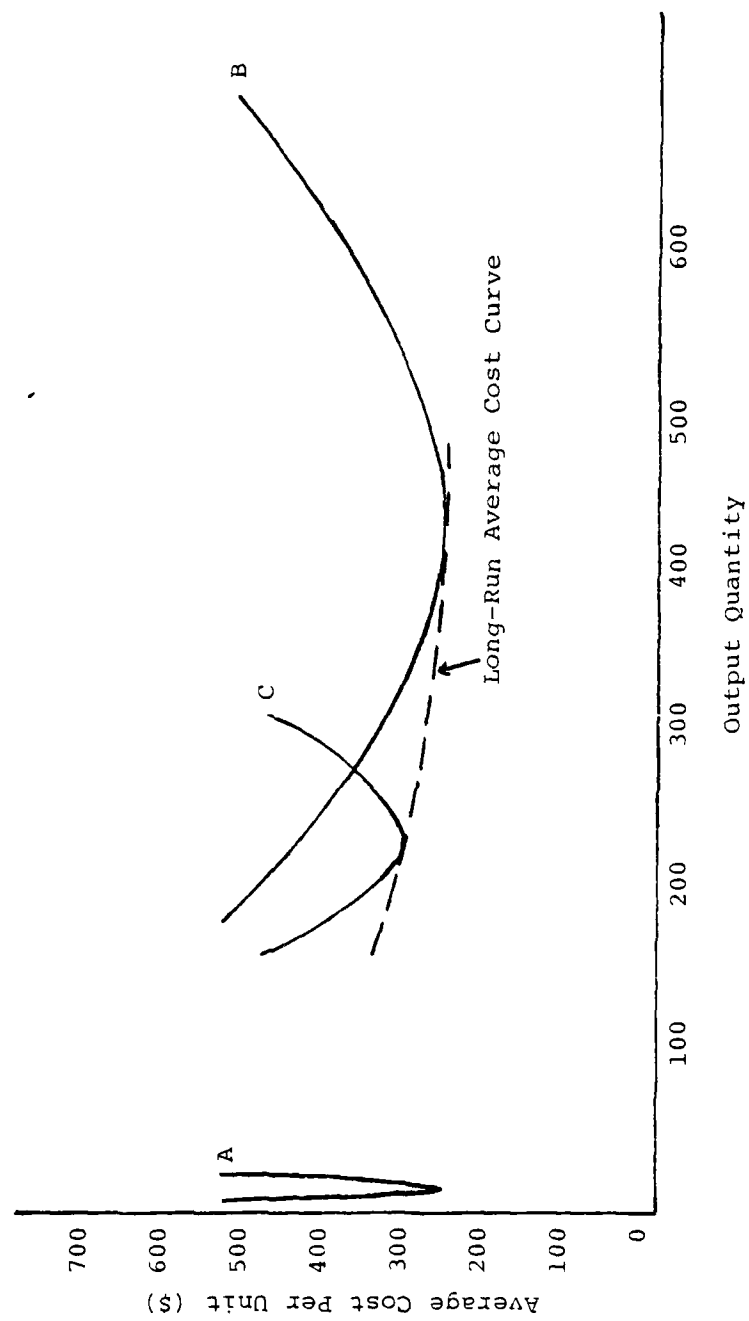


TABLE 15  
Auto Painting Firm Capital Investment

Firm	Facility Cost/Month	Equipment Replacement Costs,	Resources
A	\$ 210.00	\$ 2,000	Primer gun Paint gun Compressor Sander 2 men
B	1,469.33	85,000	2 drying ovens 2 paint spray booths 4,500 square feet 5 men
C	1,250.00	60,000	1 drying oven 1 paint sprat booth 8,000 square feet 14 men

smaller volume of output (see Tables 11 and 12). The data and curves suggest that, for this industry, a capital-intensive production base is more efficient and more effective than a labor-intensive production base.

Discussion to this point has omitted consideration of Firm A. From Table 15, it is noted that Firm A is smallest in scale and, if economies of scale exist, should exhibit higher average costs than Firms B or C. Figure 5 shows this not the case. Firm A is a comparatively small, two-man shop that operates on a low capital investment in terms of space allocation, productive plant supplies, and manpower. Although units are produced at a lower average cost, the product is not precisely the same as the product of Firms B and C in that Firm A lacks a drying oven and cannot produce baked-enamel work. If a drying oven were to be added to the productive plant of Firm A, that addition would likely more than double the fixed costs of the Firm, which would have the effect of driving the average cost curve higher on the graph or, in other words, increasing the average costs per unit of the Firm. It is speculated that such an increase might be sufficient to place the short-run average cost curve upon the long-run average

cost curve shown in Figure 4 as a dashed arc, and thus remove the apparent anomaly that is shown in the figure. If the curve of Firm A may be ignored on the ground that Firm A did not produce the same product as Firms B and C, then it would seem possible to suggest that economies of scale are demonstrated by the sample auto painting firms.

## CHAPTER 5

### BASE SAMPLE DATA

#### Introduction

As stated in the section on Data Collection beginning on page 22, the data were collected by direct contact with the bases in the sample and from the Air Force Maintenance Data Collection (MDC) System at Headquarters, Air Force Logistics Command (AFLC). The data herein presented are in summary form and separated into subsections corresponding to the three source types discussed in Chapter 2. Combinations of How Malfunction Codes (HMCs) and Action Taken Codes (ATCs) for which no man-hours were recorded have been omitted from the tables in order to improve clarity of presentation.

#### Data Presentation

Vehicle Data.--Man-hours expended for corrosion maintenance by the vehicle maintenance work centers in the sample were obtained by direct communication with the Reports and Analysis Sections of the respective transportation squadrons. Corrosion maintenance consisted of painting plus necessary preparatory work (5;12;19;29;53). The data appear in Table 16.

TABLE 16  
Vehicle Data

Base	Man-Hours	Contract Man-Hours	Vehicles Supported
Pease	3451.20	950.67	495
Dyess	616.00	0.00	543
Barksdale	1158.00	0.00	609
Ellsworth	233.33	0.00	857
Robins	3870.00	0.00	680
Total	9328.53	950.67	3184
Grand Total: 10,279.2			

GSC 02000 Data.--General Support Code (GSC) 02000 man-hour data and average number of Aerospace Ground Equipment (AGE) supported (assigned) were obtained directly from the bases in the sample (6;8;10;13;14). The man-hour data for the Munitions Maintenance Squadron (MMS) Equipment Maintenance Branches at Robins Air Force Base (AFB) and Pease AFB were not available. Munitions Maintenance Squadron (MMS) AGE corrosion maintenance at Robins AFB was accomplished as a part of scheduled equipment inspections and was recorded together with inspection man-hours under different codes (7). The type of aircraft supported at Dyess AFB did not require an MMS Equipment Maintenance Branch.(13). The large number of units supported by the MMS Equipment Maintenance Branch at Barksdale AFB was a result of a squadron policy which shifted work normally performed by work centers owning various equipment to the Equipment Maintenance Branch (14) (See Table 17).

MDC Data.--MDC data were obtained from HQ AFELC. Twenty-two combinations of EMCs and ATCs (see Tables 3 and 4 for code definitions) were selected as representing corrosion control and corrosion preventive actions and are shown in Table 18. Tables 19 and 20 portray the data recorded for the selected code combinations.

TABLE 17  
GSC 02000 Data

Base	FMS		OMS		MMS		Total *
	Man-Hours/Units		Man-Hours/Units		Man-Hours/Units		
Barksdale	2597.7/230		406.7/215		87.0/119		3004.4/445
Dyess	413.0/230		446.9/164				859.9/394
Ellsworth	2397.3/195		2326.1/182		356.5/36		4723.4/377
Pease	2354.5/250		2185.1/240				4539.6/490
Robins	705.8/135		370.0/140		/35		1075.8/275
Total	8468.3/1040		5734.8/941				14203.1/1981

\*Figures do not include MMS data.

TABLE 18  
HMC/ATC Combinations

HMC	ATC	ATC	ATC
910	F		Z
170	F	V	Z
667	F	V	Z
116			Z
846	F		Z
117		V	Z
230		V	Z
425	F		
520	F	V	Z
865	F		
935	F	V	

TABLE 19

## Man-Hours By Work Center and By Base

Work Center	Barksdale	Dyess	Ellsworth	Pease	Robins	Total	Total
FMS AGE	437.8/52.5	2.0/0.0	56.0/0.5	72.5/6.7	245.9/8.0	814.2/67.7	881.9
FMS RPR	1.3/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	1.3/0.0	1.3
Subtotal	439.1/52.5	2.0/0.0	56.0/0.5	72.5/6.7	245.9/8.0	815.5/67.7	883.2
OMS SEQ	43.5/0.0	27.0/0.0	0.0/0.0	4.5/0.0	15.1/0.0	90.1/0.0	90.1
OMS NPA	0.0/8.0	0.0/0.0	8.0/0.0	0.0/0.0	0.0/0.0	8.0/8.0	16.0
Subtotal	43.5/8.0	27.0/0.0	8.0/8.0	4.5/0.0	15.1/0.0	98.1/8.0	106.1
FMS AGE	20.9/0.0	5.5/0.0	83.0/0.0	16.5/0.5	0.0/0.0	125.9/0.5	126.4
Total	503.5/60.5	34.5/0.0	147.0/0.5	93.5/7.2	261.0/8.0	1039.5/76.2	1115.7

Legend: FMS AGE--FMS AGE Branch

FMS RPR--FMS Repair and Inspection Section

OMS SEQ--OMS Support Equipment Branch

OMS NPA--OMS Non-Powered AGE Section

FMS AGE--FMS Equipment Maintenance Branch/Section

The "/" between figures in the table separates man-hours recorded from January through June 1975 and man-hours recorded from July through December 1975.

TABLE 20  
Man-Hours By Combination and Base

HMC/ATC	Barksdale	Dyess	Ellsworth	Pease	Robins	Total	Total
170 F				4.0/0.0		4.0/0.0	4.0
435 F					4.0/0.0	4.0/0.0	4.0
846 F					10.0/0.0	10.0/0.0	10.0
117 V		2.0/0.0			0.5/0.0	2.5/0.0	2.5
170 V	17.9/8.0	0.5/0.0	6.3/0.0		33.3/0.0	58.0/8.0	66.0
230 V	205.7/6.0	9.8/0.0	110.6/0.5	33.2/2.0	39.6/0.0	403.9/8.5	412.4
510 V	2.5/0.0					2.5/0.0	2.5
667 V			9.0/0.0			9.0/0.0	9.0
117 Z	79.6/2.0	9.5/0.0		7.0/2.0		91.6/4.0	100.1
170 Z	171.3/34.5	11.8/0.0	4.6/0.0	42.5/3.2	162.6/8.0	392.8/35.7	428.5
230 Z			16.5/0.0	1.8/0.0	3.0/0.0	21.3/0.0	21.3
667 Z	26.5/20.0				8.0/0.0	34.5/20.0	54.5
910 Z		0.9/0.0				0.9/0.0	0.9
Total	503.5/60.5	34.5/0.0	147.0/0.5	93.5/7.2	261.0/8.0	1039.5/76.2	1115.7

### Analysis

The man-hours expended on vehicle corrosion maintenance (Table 16), at first glance, would appear to be highly erratic and suspect. Five explanations are proposed:

1. Errors may have existed in the recorded data.
2. Errors may have occurred in the collection and/or transmission of the data from the sources to the researchers.
3. Differences may have existed among the vehicle corrosion maintenance programs and/or management thereof.
4. Man-hour availability among the bases may have been a factor.
5. Differences in climate due to the geographic location of the bases in the sample may have caused differing corrosion maintenance requirements.

Any one or any combination of the suggested explanations might account for the wide variance in man-hours expended by the sample bases. There is no evidence available to the researchers, however, to support the first four suggested explanations; and, consequently, they must be regarded as pure speculation. On the other hand, the geographic location of the five bases would seem to suggest that the man-hour data are not completely unreasonable. Pease AFB is located in the state of New Hampshire near the coast. One might expect increased corrosion due to salt air from the ocean and salts placed upon roads during winter. Barksdale AFB is located in

northern Louisiana and Robins AFB is situated in central Georgia where warm, humid weather could be expected to increase corrosion. The data from Dyess AFB would seem fairly reasonable in view of the number of vehicles supported and the location of the base in north central Texas. One might expect the data from Ellsworth AFB to be slightly greater than that from Dyess AFB due to the location of Ellsworth AFB in western South Dakota, with a relatively dry climate, and to the larger number of vehicles supported. However, such was not the case; and only speculation about the reasons for the disparity is possible without closer, on-the-site investigation.

The GSC 02000 data, omitting consideration of all MMS Equipment Maintenance Branch data, would appear consistent when viewed in light of the geographical location of the bases and the number of units supported. Unlike the vehicle corrosion maintenance data, the GSC 02000 data for Ellsworth AFB and Pease AFB are fairly equal, as might be expected. Again, the smallest number of man-hours was recorded at Dyess AFB.

The MDC data in Tables 19 and 20 show a marked difference in recorded man-hours between the first six months of OY 1975 and the last six months. This difference might possibly be attributed to seasonal differences in weather which could affect corrosion maintenance (primarily painting) and which, as a consequence, may have forced uneven scheduling of corrosion maintenance. The difference

might also have been caused by a change in the format for reporting maintenance data which took place on 1 July 1975 (17). In view of the fact that the first six months of recorded data included both winter and summer months, it would appear likely that the disparity in recorded man-hours between the two halves of CY 1975 was due more to the change in data reporting format than to seasonal differences in weather.

Table 19 displays two work centers for Field Maintenance Squadron (FMS) and Organizational Maintenance Squadron (OMS) data. This is due to differences in data reporting by the work centers in the sample. It was found by trial and error through multiple runs of the MDC tapes using different work center codes that corrosion maintenance data for the FMS and OMS corrosion work centers were not always recorded to the performing work center but rather were recorded to the parent branch. An example is man-hours normally expended by an OMS Non-powered AGE Section appearing under the parent Support Equipment Branch. Accordingly, Table 19 displays the data as actually recorded. It is nevertheless possible to credit the man-hours expended by the work centers listed in Table 19 to the appropriate FMS and OMS corrosion work centers listed on page 13. Standard organizational diagrams found in AFM 66-1 (-2:2-5; 2-6) clearly show the equivalence of the reporting sections to the parent branch and vice versa. For example, an FMS Repair and Inspection Section is a section within an FMS

AGE Branch and is, therefore, a part of an FMS corrosion work center.

Table 20 displays the data recorded by HMC/ATC combination and by base. The two combinations of HMC/ATC with the greatest number of recorded man-hours are 230 V (dirty, contaminated--cleaned) with 412.4 man-hours and 179 Z (corroded, mild to moderate--corrosion repair) with 428.5 man-hours. The number of man-hours identified specifically as corrosion maintenance was 562 hours, or approximately 50.4 per cent of the total number of man-hours recorded for the HMC/ATC combinations identified by the researchers as representing corrosion maintenance. The figure of 50.4 per cent would appear to give weight to the assumption on page 22 that some corrosion control actions are perceived merely as cosmetic or good housekeeping actions.

#### Limitations

The vehicle corrosion maintenance data presented considerable difficulty. No data were available on man-hours expended on washing vehicles. In addition, it was found impossible to obtain corrosion maintenance data for CY 1975 for four of the bases. With one exception, the data were not entered into a mechanized storage and retrieval system at the sample bases, but rather were recorded upon individual work orders which were maintained for a period of 180 days (12;19;29;53). The exception was Robins AFB which identified vehicle corrosion maintenance for CY 1975 with a special computer code (5) and maintained computerized records.

Vehicle corrosion maintenance (complete painting) at Pease AFB was performed by a civilian contractor. The man-hour datum for Pease AFB was calculated from the dollar amount paid to the contractor. The dollar figure obtained for vehicle corrosion maintenance was \$3,565 for the first five months in CY 1976. The Transportation Squadron Executive Officer at Pease AFB indicated (19) that the figure of \$3,565 was representative of any five month period; consequently, it was assumed that the average amount paid for vehicle corrosion maintenance per month ( $\$3,565$  divided by 5) when multiplied by twelve would yield an average, annual dollar amount representative of the amount spent for vehicle corrosion maintenance for CY 1975. These calculations were performed, and the resulting average, annual dollar figure was divided by nine, the conversion factor used by the Air Force to convert dollars spent for all contract maintenance into man-hours (32:42410.7), to obtain the figure for CY 1975 contract man-hours which appear in Table 16.

Additional vehicle corrosion maintenance was performed at Pease AFB by the Vehicle Maintenance Branch in the form of partial or spot painting. Man-hour data for the first five months of CY 1976 were obtained. As in the case of contract dollars, a monthly average was computed and multiplied by 12 to obtain an average figure for annual man-hour expenditure. It was assumed that several variations in man-hour expenditure due to adverse

weather or other factors were captured in the data for the five month period, i.e., January through May 1976. This assumption permitted the calculation of an average figure for annual man-hour expenditure (see Table 16) and strengthened the further assumption that the annual figure so derived was representative of the actual man-hour expenditure for CY 1975.

The man-hour figures shown in Table 16 for the remaining three bases were arrived at by doubling the man-hours recorded during the period January through June 1976. As in the case of Pease AFB, this was done under the assumption that the man-hours expended in CY 1975 during the same months were comparable and that, as the period represented by the figures extended from midwinter through midsummer, seasonal variations in man-hour expenditures were captured, and the figures for the preceding six months would also be similar. The variances in man-hours thus calculated for the bases in the sample can perhaps be explained by, once again, geographical location of the bases; nevertheless, the magnitude of the variances tends to cast doubt upon the validity of the data and/or the assumptions made.

The GSC 02000 data also exhibit large variances, but not in the same pattern as the vehicle corrosion maintenance data; however, the GSC 02000 data appear to conform more closely with the suggested explanation of variances having been caused by the geographic location of the bases. Additionally, the GSC 02000 data failed to capture man-hours

expended by all MMS Equipment Maintenance Branches/Sections. The 02000 code includes several cleaning actions such as washing, wiping, vacuuming, and polishing, and the data do not distinguish among them.

The MDC data show a great disparity in man-hours expended between the first and last halves of CY 1975 (1039.5 versus 76.2) giving rise to doubt as to the validity of the data. The MDC data, like the vehicle corrosion maintenance data and the GSC 02000 data, also exhibit large variances in man-hours among the bases.

## CHAPTER 6

### CORROSION CENTER MODEL

In this chapter, man-hour requirements are computed for a consolidated corrosion control work center and compared with the average man-hours expended by the five sample bases. Man-hour costs are also computed and compared.

The specific design of a consolidated corrosion control facility is beyond the purview of this research; indeed, the primary emphasis and interest lie in the area of man-hour comparison. On the other hand, the physical plant of a consolidated corrosion control facility cannot be ignored. The capital investment costs of such a facility and installed equipment are an integral and essential part of any cost study and must be considered. Accordingly, then, the following section examines five alternative facility and equipment situations and the costs associated with each. A summary comparison appears in Table 21.

TABLE 21  
Comparative Annual Facility Costs

New Facility	Modified Facility			Existing Facility	
	Option A	Option B	Option C	Option D	Option E
	\$8,615	\$9,760	\$3,368	\$2,600	\$0

NOTE:

Option A.--The figure is the sum of the annual costs of facility and vehicle wash equipment.

Option B.--The figure is the sum of the annual costs of facility, facility modification, and vehicle wash equipment.

Option C.--The figure is the sum of the annual costs of facility modification and vehicle wash equipment.

Option D.--The figure is the annual cost of vehicle wash equipment; no other capital investment required.

Option E.--No Capital investment required.

### Capital Investment

A basic assumption is implicit in the five alternative facility situations which follow: all major equipment required for a consolidated corrosion control facility such as air compressors, paint sprayers, sand blasting machinery, and the like is present and available for installation in a consolidated corrosion control facility at any given Air Force Base except for automated vehicle washing equipment. The underlying rationale is that this type of equipment is present in existing vehicle maintenance paint shops and/or field maintenance squadron paint shops and would become superfluous to those shops, as would the shops themselves, upon the construction or establishment of a consolidated corrosion control facility.

### New Facility

The definitive drawing for an eight stall automotive shop found in AFM 88-2, Air Force Design Manual, Definitive Designs of Air Force Structures, was selected as the basis for computing construction cost for a consolidated corrosion facility (31:AD 35-02-62). This drawing was selected because it takes into consideration such factors as floor loading and vehicle size. In addition,

the dimensions of the illustrated facility (48' x 84') are sufficiently large to accommodate a 16' x 60' auto wash installation, at least three 12' x 24' paint drying rooms, two 16' x 28' rooms for stripping and painting, an equipment room, a supplies room, an office, and a latrine.

The method commonly used by the Air Force to obtain facility cost is to multiply the floor area in square feet by a cost factor in dollars per square foot (48). The cost factor for an automotive shop was obtained from an updated list of cost factors for different types of facilities used by Air Force installations for costing proposed construction projects (23). Straight line depreciation was used to convert the capital investment cost to an annual cost spread over the life of the facility. The economic life of the facility was assumed to be 25 years (23). The figures used and results were:

Floor space	4,032 sq. ft.
Cost factor	\$37.30 per sq. ft.
Total cost	\$150,393
Economic life	25 years
Annual cost	\$6,015

An automated vehicle washing installation was estimated to cost \$39 thousand. Such an installation would require a floor space of 16' x 60' and would include scrubber brush, high pressure water and drying machinery, and a conveyor (24). Again using straight line depreciation and an economic life of 15 years (20), an annual cost over the life of the equipment of \$2,600 was calculated. The resulting sum of annual equipment cost and annual facility cost appears under Option A in Table 21.

Modified Facility.--It is possible that a given Air Force Base might have a facility available, or which would be made available, which with modification could be used as a consolidated corrosion control facility. Two situations are envisioned: the first is that the facility to be modified has some amount of economic life remaining and must be removed from some other use necessitating consideration of a capital investment cost, and the second is that the facility is unused and/or the economic life of the facility has expired, in which case capital investment can be omitted from consideration. These two situations appear in Table 21 as Options B and C. The economic life of a facility is shorter than the physical

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or serviceable life (20), and it is assumed that the facility to be modified could be used for the length of the economic life of the modifications made to it.

The definitive drawing of an automotive maintenance garage was selected as an example structure to be modified (31:AD 36-10-09). Annual cost was calculated in the same manner as for a new facility as previously described. Modification costs were calculated based upon a cost factor of \$2.40 per square foot of eight inch concrete block wall (15). The same cost factor was used to calculate the cost of ceiling construction. The selected drawing indicates a floor space for the automotive maintenance garage somewhat greater than that of the automotive shop previously discussed. The square footage required for modification was based upon the addition of sufficient walls and ceiling to provide the same number and type of rooms described in the previous section. The same figure for annual cost of vehicle washing equipment was used. The data involved were:

Annual Facility Cost Data

Floor space	5,940 sq. ft.
Cost factor	\$26.90 per sq. ft.
Total cost	\$159,786
Economic life	25 years
Annual cost	\$6,391

Annual Modification Cost Data

Wall and ceiling	
area	8,010 sq. ft.
Cost factor	\$2.40 per sq. ft.
Total cost	\$19,224
Economic life	25 years
Annual cost	\$768

Existing Facility.--Two final situations are depicted in Table 21. In both cases, it was assumed that a large vehicle maintenance and administration facility was present on some given Air Force Base and that the facility contained the necessary rooms and equipment needed for a consolidated corrosion control work center. Definitive drawings AD 35-02-56, 57, and 58 found in AFM 88-2 (31) depict such a facility. In the first case (Option D, Table 21), it was assumed necessary to purchase and install vehicle washing equipment, and in the second case (Option E, Table 21) that vehicle washing equipment was present.

Model Description

The vehicle washing portion of the consolidated corrosion control facility was envisioned to be completely automatic and operable by the customer. It would include equipment for spraying vehicles and equipment with high pressure water and a water/wax mixture if desired. It

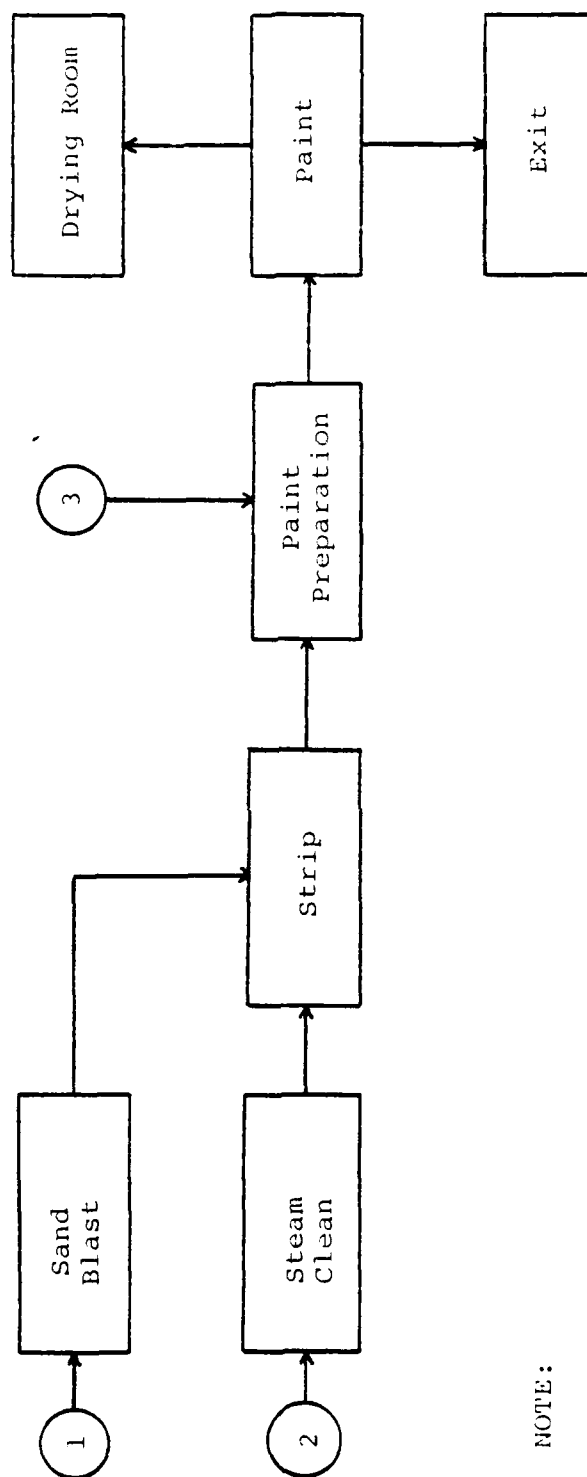
would also include revolving brushes for scrubbing sides and tops of vehicles and equipment and an air blower for drying. Finally, it would include a conveyor for pulling equipment through the various stations at the proper rate of speed.

The workflow model for painting is shown in Figure 3. The operations illustrated in the figure were developed by the researchers based upon information provided by paint shop personnel at Wright-Patterson AFB (52). The model provides for three distinct job types: complete painting of non-powered Aerospace Ground Equipment (AGE) involving sand blasting, complete painting of vehicles and powered AGE involving steam cleaning, and partial or localized painting. Drying is optional, depending upon job type and prevailing weather at the facility location.

The production structure of the work center was assumed to be a job process layout where the tasks were grouped according to the function they performed (8:111); e.g., a steam cleaning cell, a sand-blasting cell, a stripping room, etc. A job process layout was assumed in lieu of an assembly line based on the following factors:

1. The nature of the tasks appeared to lend themselves to a job process flow.

Fig. 6. Corrosion Work Center Workflow



## NOTE:

1. Total Corrosion Rehabilitation: Non-Powered Age.
2. Total Corrosion Rehabilitation: Vehicles and Power AGE.
3. Localized Corrosion Control and Prevention.

2. The anticipated volume through the facility would not be large enough to sustain an assembly line process.

3. The sharp diversity in the time interval of tasks was not conducive to an assembly line process, i.e., a smooth flow of work did not appear possible.

4. The pattern of workflow through the work center was anticipated to be highly variable.

Units to be processed would likely range from B-1 stands (non-powered AGE) to aircraft towing tractors, and the tasks performed on the input units would vary from minor touchup painting to complete painting. In view of the preceding factors, the production process best suited to handle the high variability was a job process layout (8:119).

Production units would be input to the facility through a scheduling function whose task would be to ensure continuous throughput. In order to minimize slack time, it would be necessary for the scheduling function to create small queues at the beginning of the workflow. A queue of units awaiting processing would ensure a continuous workflow through the work center and thereby minimize slack time.

Job Standards.---It was necessary to establish man-hour standards for vehicle and equipment washing and painting in order to develop annual man-hour requirements for a consolidated corrosion control work center for comparison with the man-hour data presented in Chapter 5. Research failed to disclose any generally accepted standards. As a consequence, man-hour standards for painting were developed by the researchers using the best judgment technique employed by Air Force Management Engineering Teams in similar situations (46:5.37). The technique involves establishing a man-hour standard for a stated job, task, or group of tasks by combining information provided by workers and supervisors involved with the job under consideration with the experience of the investigator.

Supervisory personnel of two maintenance work centers at Wright-Patterson AFB were consulted by the researchers to arrive at man-hour standards for powered and non-powered AGE (2; 28; 52). The standards for powered and non-powered AGE were average times for all AGE falling within either category.

The work environment in which the man-hour standards were estimated was similar to the job process layout envisioned for the corrosion control facility in that job

tasks were grouped by function. At that point, however, similarities ceased. The following differences were noted:

1. The workflow through the work centers at Wright-Patterson AFB was not driven by a schedule,
2. The work centers performing the maintenance were not co-located within a single facility, and
3. Specialization of effort did not exist for the total job tasking.

The steam-cleaning facility, the sand-blasting facility, and the painting facility necessary for processing powered and non-powered AGE were physically separated. As a result, it was necessary to move units being processed between work centers in order to accomplish the complete job. In the case of non-powered AGE, aircraft maintenance technicians performed all required tasks. Conversely, for powered AGE the AGE technicians performed only steam-cleaning. AGE units were then transferred to the paint shop where painting technicians accomplished stripping and painting.

In spite of the lack of specialization and the decentralization of job tasking within the workflow for painting activity, the physical processing of job tasks was found to be that of a job process layout. Since this

matched to a large extent the assumption for the consolidated facility of a job process layout, it was felt reasonable to use the two work centers as a basis for developing workflow tasks and man-hour standards for powered and non-powered AGE for the consolidated corrosion control work center. The resulting man-hour standards appear in Tables 22 and 23.

A third maintenance work center was interviewed in order to develop man-hour standards for painting vehicles. A man-hour standard of 31.27 man-hours for complete vehicle painting was developed. This standard represents a weighted average of time standards developed and used by the vehicles maintenance facility at Wright-Patterson AFB. The weighting factors employed were the number of vehicles supported by the vehicle maintenance facility falling within each of eighteen vehicle types selected by the researchers as typical examples of vehicles supported by a consolidated corrosion control work center (see Appendix B). The weighted average was calculated by multiplying each weighting factor by its corresponding time standard, summing the products, and dividing the result by the sum of the weighting factors. The man-hour standard for partial

TABLE 22

Powered AGE Man-Hour : standard for an Average Production Unit

Job Tasks	Complete Painting (man-hours)	Touch Up (man-hours)
<u>I. Steam Cleaning</u>		
1. Preparation (setup time, warmup)	.25	
2. Steam cleaning operation	1.0	
3. Shutdown (includes cleanup)	.25	
<u>II. Stripping</u>		
1. Masking	1.0	
2. Application of paint remover	3.0	
3. Removal of paint remover (strip to bare metal)	22.5	
4. Brnish, grind, sanding, etc.	2.0	0.5
<u>III. Painting</u>		
1. Preparation (remasking)	4.0	0.5
2. Paint unit	3.0	1.0
3. Detail unit (stenciling, reflectorization)	3.0	0.5
TOTAL	40.0	2.5

TABLE 23

Non-Powered AGE Man-Hour Standard for an Average Production Unit

Job Tasks	Complete Painting (man-hours)	Touch Up (man-hours)
<u>I. Sandblasting</u>		
1. Preparation (remove hoses, actuators, reflective tape)	3	
2. Sandblasting operation	4	
3. Cleanup (includes replacement of hoses and actuators, blow out wheel bearings, retape)	3	0.33
<u>II. Burnish, Grind, Sand</u>		
<u>III. Painting</u>		
1. Prime	.5	
2. Paint	.67	0.33
3. Detail (stencil and decal)	.5	
<u>TOTAL</u>	<u>11.67</u>	<u>0.67</u>

vehicle painting was a best judgment based upon the standard used by the vehicle maintenance facility.

The man-hour standard developed for washing vehicles and equipment in an automatic vehicle washing installation was strictly an estimate made by the researchers based upon experience with similar commercial facilities. It was estimated that the processing time of an automatic vehicle washing installation would be approximately 12 minutes. Since the only man-hours involved would be that of the customer, the man-hour standard, then, became the same as the duration of the washing/drying process, or 0.2 manhours. Transit time to and from the consolidated corrosion control facility was neglected due to the numerous distances which would likely be involved and which would vary from base to base.

Job Scheduling.--A second set of factors necessary to the development of annual man-hour requirements for a consolidated corrosion control work center was scheduling rates for vehicles and AGE. These rates were developed in the form of percentages of vehicles, and AGE assigned to a base to be scheduled each year for painting and each month for washing. The rates appear in Table 24. The percentages of vehicles to be scheduled for partial and complete painting each year were developed, again, using the best judgment technique (9). The percentages of AGE

TABLE 24  
Corrosion Work Center Scheduling Estimates

Assumption Set A		Total Assigned	%/Yr/Paint	Qty/Yr	%/Mo/Wash	Qty/Mo
Vehicles	Total	637	10%	64	200%	1,274
	Partial		45	287		
Powered AGE	Total	208	30%	62	200%	416
	Partial		70	146		
Non-Powered AGE	Total	188	30%	56	---	---
	Partial		70	132		
Assumption Set B		Total Assigned	%/Yr/Paint	Qty/Yr	%/Mo/Wash	Qty/Mo
Vehicles	Total	637	5%	32	200%	1,274
	Partial			242		
Powered AGE	Total	208	15%	31	200%	416
	Partial		68	142		
Non-Powered AGE	Total	188	15%	28	---	---
	Partial		68	128		

to be scheduled for partial and complete painting each year and the percentages of vehicles and AGE to be scheduled for washing each month as listed in the Assumption Set A column of Table 24 are based upon observation and experience of the researchers. The Assumption Set B column lists a second set of scheduling rates in the form of percentages which are subsequently used in Table 25 along with the Assumption Set A percentages to illustrate the impact of scheduling rates upon annual man-hour requirements for the hypothetical consolidated corrosion control facility. The figures given in Table 24 for total vehicles and AGE assigned are the average of the numbers of assigned vehicles and AGE at the sample bases.

#### Analysis

Average man-hours expended by the corrosion work centers in the sample and projected manhours for a consolidated corrosion control work center are compared in Table 26. Man-hour savings due to consolidation are also shown along with computed dollar savings.

Table 27 shows total annual savings in dollars for each of the five facility situations discussed earlier in the chapter. The dollar amounts shown for the facility options correspond to Assumption Set A in Table 21. The figures in the table indicate that a consolidated corrosion control work center would realize dollar savings through reduced man-hour requirements, but the savings

TABLE 25  
Corrosion Work Center Man-Hour Estimates

	Job Standard	Assumption Set A		Assumption Set B	
		Scheduled Quantity	Total Man-Hours	Scheduled Quantity	Total Man-Hours
Vehicles	Total	64	2,001.28	32	1,000.64
	Partial	287	717.5	242	605
Powered AGE	Total	62	2,480	31	1,240
	Partial	146	365	142	355
Non- Powered AGE	Total	56	653.52	28	88.44
	Partial	132	326.76	128	85.76

TABLE 26  
Projected/Recorded Man-Hour Comparison  
(per calendar year)

	Washing Actual	Washing Projected	Savings Man-Hours/Dollars
Vehicle	15,288 (estimated)	3,057	12,231/\$ 46,233
Powered AGE	1,792	998	794/\$ 3,001
Total	17,080	4,055	13,025/\$ 49,234
	Painting Actual	Painting Projected	Savings Man-Hours/Dollars
Vehicles	2,024	2,718	-694/\$- 2,623
AGE	125	3,586	-3,462/\$-13,086
Total	2,148	6,304	-4,156/\$-15,709
GRAND TOTAL	19,228	10,359	8,869/\$33,525

TABLE 27  
Dollar Savings Analysis  
(per calendar year)

	Option A (\$8,618)	Option B (\$9,760)	Option C (\$3,368)	Option D (\$2,600)	Option E (\$0)
Man-hour savings, painting	\$-15,709	\$-15,709	\$-15,709	\$-15,709	\$-15,709
Total savings over the option	-23,697	-24,839	-18,447	-17,679	-15,709
Man-hour savings, washing	\$ 49,234	\$ 49,234	\$ 49,234	\$ 49,234	\$ 49,234
Total savings over the option	40,618	39,474	45,866	46,634	49,234
Total man-hour savings	\$ 33,525	\$ 33,523	\$ 33,523	\$ 33,523	\$ 33,523
Grand total savings, painting and washing over the option	24,907	23,763	30,155	30,923	33,523

would be due entirely to the automated vehicle washing installation, and the consolidated painting function would, in fact, be costlier in terms of man-hour requirements than the existing situation. This remains true even when the figures in Assumption Set B, Table 21, are substituted, yielding a negative savings for painting of \$6,134 and a corresponding increase in overall savings.

Washing Man-Hours.--All man-hours in Table 20 recorded against an Action Taken Code (ATC) of V (clean) were assumed to represent man-hours expended in washing equipment. Although the How Malfunction Codes (HMC) associated with this ATC would seem to indicate a maintenance action more on the order of painting (see Table 3), it is suggested that painting and similar maintenance actions would more likely have occurred with an ATC of F (repair) or Z (corrosion repair). Accordingly, the V coded man-hours were averaged, and the resulting figures was added to the average of the GSC 02000 man-hours appearing in Table 17.

As indicated in Chapter 2, GSC 02000 maintenance includes, in addition to washing, actions such as snow and ice removal, vacuuming, wiping and polishing. It was not possible to identify man-hours expended only in washing actions. In order to eliminate the possibility of including maintenance man-hours expended upon aircraft,

only those man-hours expended by the FMS AGE Branches in the sample were selected as representing washing actions. It was also assumed that, considering the duties of an FMS AGE Branch as described in Chapter 3, it would be more likely for an AGE Branch to have expended a large portion of its recorded GSC 02000 man-hours upon washing actions than either of the other two corrosion work centers recording GSC 02000 man-hours expenditures. The total GSC 02000 man-hour figure shown in Table 8 for the FMS AGE Branches in the sample was divided by five to arrive at an average figure, and this average was added to the average of the ATC "V" man-hours shown in Table 20. The sum appears in Table 26 under the cross heading of Powered AGE, Washing (manhour) Actual.

The figure in Table 26 for actual man-hours expended washing vehicles is an estimate. It was assumed that all vehicles were washed twice monthly and that an average of one man-hour was required for each washing, or equivalently, that 24 man-hours were expended each year washing each vehicle. The man-hour figure, then, was calculated by multiplying the average of the number of vehicles assigned to the bases in the sample (see Table 24) by 24 man-hours per year.

Painting Man-Hours.--All man-hours in Table 20 recorded against the ATCs of F and Z were assumed to

represent man-hours expended in painting equipment. These man-hours were averaged, and the resulting figure appears in Table 26 under the cross heading of AGE, Painting (manhours) Actual.

The total man-hour figure in Table 16 is the quantity of man-hours expended by the bases in the sample upon painting vehicles. An average man-hour figure is shown in Table 26.

Man-Hour Cost.--The man-hour data appearing in Chapter 5 represent direct labor man-hour expenditures. Supervision, or overhead, man-hours are not included. The same is true for the projected man-hour figures appearing earlier in this chapter. With this in mind, it was deemed necessary to develop an average cost factor for direct labor only which could be applied to man-hour figures to obtain man-hour costs.

There are nine enlisted ranks within the Air Force, and the top three ranks are generally regarded as management. The top three ranks were not considered in the development of a cost factor. The method used to arrive at a cost factor was to multiply the hourly wage for each of the lower six ranks ( $35:525/20$ ) by weighting factors, sum the products, and divide the results by the sum of the weighting factors. The weighting factors were chosen as representing the typical grade structure found within a

maintenance work center. It is noted that the selected weighting factors listed below in Table 28 follow roughly a normal distribution.

TABLE 28  
Airman Hourly Wage

Weighting Factor (ranks assigned)	Rank	Hourly Wage	Total
1	E6	\$5.59	\$ 5.59
2	E5	4.75	9.50
5	E4	3.92	19.60
4	E3	3.29	13.16
2	E2	3.04	6.08
<u>1</u>	E1	2.77	<u>2.77</u>
15			\$56.70

NOTE:

$$\text{Cost Factor: } \frac{\$56.70}{15} = \$3.78$$

## CHAPTER 7

### SUMMARY

#### The Problem

Damage to equipment and facilities caused by corrosion is a multi-billion dollar problem in the United States. Every person, business, and industry owning equipment, buildings, and other material objects is affected, and the U. S. Air Force is no exception.

This is a day and time of inflation, rising costs, and diminishing defense budgets. In order to maintain the level of military preparedness expected by and necessary to the American public, military managers must constantly seek better and more efficient ways of operating the business of defense.

Much time, effort, and supplies are expended almost daily on every Air Force installation in an attempt to control or prevent corrosion of equipment and the consequent monetary and mission capability losses corrosion damage causes. Specialists in many fields are periodically diverted from the work for which they were trained in order to wash, clean, paint, and otherwise combat corrosion. Every work center owning equipment on every installation is charged with the task of corrosion prevention and control.

Although there are costs associated with corrosion damage, there are also costs involved in its control and prevention. Reduction of the costs incurred in an effort to control or prevent corrosion appeared to the researchers to offer an area for investigation.

#### The Approach

On any particular Air Force installation, corrosion prevention and control activities in the form of washing and painting of vehicles and equipment are performed by a number of maintenance work centers. The economic concept of economies of scale suggested the idea that consolidation of corrosion control and prevention activities under a single, specialized work center might provide an increase in the scale sufficient to realize economies through specialization of work, automation, etc., and thereby allow a reduction in the average cost per unit of output while at the same time maintaining, as a minimum, the same volume of production as the combined output of the individual maintenance work centers.

In order to rigorously test the hypothesis, it would have been necessary to build a consolidated corrosion control facility at some installation, compare resulting costs and output with those previously experienced by the maintenance work centers at the same installation, and then generalize the results with some stated confidence level to other installations. As this method was infeasible, the research question method was used to investigate the

hypothesis. The approach to answering the research question involved three separate avenues: logical argument was advanced to suggest that consolidation of corrosion prevention and control activities under a single, specialized work center would result in economies of scale; two industries, auto laundry and auto painting, were selected for the commonality of their product with the corrosion control and prevention product of maintenance work centers, and data were collected from sample firms in those industries and examined for evidence of economies of scale; and a work-flow model of a consolidated corrosion control work center was developed from which man-hour, facility construction, and equipment costs were projected and then compared with cost figures derived from averaged man-hour data collected from five Air Force installations.

#### The Data

Air Force Data.---Four maintenance work centers were selected as representing the type of work center on Air Force installations performing corrosion prevention and control activities as a part of or in addition to normal maintenance upon vehicles and/or equipment: Transportation Squadron Vehicle Maintenance Branches, Field Maintenance Squadron Aerospace Ground Equipment Branches, Organizational Maintenance Squadron Support Equipment Branches, and Munitions Maintenance Squadron Equipment Maintenance Branches/Sections. Five bases were randomly selected from

among those in the Strategic Air Command bomber wings. Strategic Air Command was chosen for the geographic and climatic variety of its bases, and bomber wings were desired in order to increase the likelihood of the presence of all of the selected maintenance work centers. Bases were limited to those located in the continental United States in order to reduce difficulty in data collection.

The man-hour data were obtained in three categories from two basic sources. Vehicle maintenance (painting) and General Support Code 02000 (washing, cleaning, etc.) were obtained directly from the bases in the sample. Man-hour data captured in the Air Force Maintenance Data Collection System were obtained from Headquarters, Air Force Logistics Command. The types of data collected were chosen as representing man-hour expenditures in corrosion prevention and control in the form of washing, cleaning, and painting. The data for the five bases were averaged in an attempt to compensate for geographic, climatic, and reporting/recording variations.

Industry Data.--The cost and output data for the auto laundry and auto painting industries were obtained by interview with representatives of sample firms (samples of convenience) from the Dayton, Ohio area. A structured interview was employed in an attempt to insure homogeneity of data input for comparison purposes.

Data Summary, Air Force.--The data obtained from the Air Force bases in the sample were erratic and seemingly inconsistent. Large differences in man-hour expenditures recorded under the Maintenance Data Collection System were noted between the first half of calendar year (CY) 1975 and the last half (example: 503.5 versus 60.5 for one base). It is possible that seasonal differences in climate and/or a change in the man-hour reporting format, which took place on 1 July 1975, might account for the large variations. Large differences in total man-hour expenditures between the bases were noted (example: 564 versus 34.5). Unfortunately, the differences did not appear amenable to explanation in terms of climatic differences or number of units supported. In addition, it was found that 79 percent of the man-hour data obtained had been erroneously credited to higher echelon work centers. Although the man-hours so discovered were included in all computations and comparisons, it would seem possible that additional, valid man-hour data may have remained undiscovered.

Vehicle corrosion maintenance man-hour data were not available for CY 1975. It was necessary to assume equivalence between the data recorded for the first half of CY 1976 and the unknown data for the first half of CY 1975 and, further, to assume similarity between man-hour expenditures for both halves of CY 1975 in order to arrive at a total man-hour expenditure for the complete CY 1975.

Although there may have been some logic behind these assumptions, and such logic was attempted, the derived data must remain suspect.

Man-hour data for the Munitions Maintenance Squadron Equipment Maintenance Branches/Sections were incomplete. GSC 02000 data were not available for three bases, consequently, no man-hour data for Equipment Maintenance Branches/Sections were used in Chapter 6 for cost comparison purposes.

No man-hour data were available for the washing of vehicles. Since this activity was an essential element of the projected consolidated corrosion control work center, it was determined impossible to omit. Therefore, it became necessary to assume a frequency and duration of vehicle washing in order to obtain a figure representing actual man-hour expenditure for that activity. As was seen in Chapter 6, the washing activity was significant in man-hour (and cost) reduction, and all figures and results are entirely dependent upon the accuracy of the assumption.

In summation, the man-hour data for the sample bases were erratic, incomplete, inconsistent, and disappointing. Assumptions were necessary to obtain some man-hour figures for the full calendar year under consideration. Lacking any other alternative, these data were used in cost comparisons in Chapter 6. However, their fragility must, of necessity, seriously weaken any conclusions concerning cost savings (or losses) of a consolidated corrosion control work center.

Data Summary, Industry.---The data collected from the sample auto laundries and auto painting firms appeared consistent and valid. Variations in the types of data reported may have biased the calculations of the short-run average cost curves. For example, one firm may have included advertising costs in the figures given for operating expenses, whereas another firm which also experienced advertising costs may have omitted them. However, as operating expenses were not broken down as to type or category, there was no way to test this possibility. It is felt that the effect of any such variations in the data collected was minimal as the critical factor in the positioning of the curves appeared to be fixed costs.

#### The Model

Facility Cost.---Five facility and equipment possibilities, ranging from construction of a completely new corrosion control facility and purchase of automated equipment, to no facility construction and no equipment purchase, were presented along with estimated costs for each. Facility costs were based upon square footage requirements for floor space or, in the facility modification alternatives, wall and ceiling area. However, an engineering study was not undertaken to determine precise requirements, therefore, the cost figures presented must be regarded at best as rough estimates.

Workflow.--Job time standards and workflow requirements for painting vehicles and equipment were developed with the aid and advice of personnel at Wright-Patterson AFB actually engaged in performing or supervising the particular jobs. The equipment and vehicles maintained by the work centers from which the job time standards and workflow requirements were developed were of the type envisioned as being processed through a consolidated corrosion control facility, i.e., military vehicles and powered and non-powered aerospace ground equipment. This fact perhaps lends some credence to the job time standards and workflow requirements which were developed.

### Conclusions

It would appear that a consolidated corrosion control facility for the three corrosion work centers, which were ultimately considered in Chapter 6, enable an annual savings in man-hours equivalent to approximately \$44 thousand, this figure being the average of the dollar savings of the five facility and equipment alternatives presented. On the other hand, the other major activity of a consolidated corrosion control facility, painting of vehicles and equipment, showed an annual loss for each of the five facility and equipment alternatives. Although the average loss for the painting activity was slightly less than half of the average gain (savings) for the washing activity resulting in an overall dollar (and man-hour)

savings by the use of a consolidated corrosion control facility, the desirability of such a facility would seem highly doubtful as the painting activity could perhaps be considered the more important of the two activities. The suggestion, of course, is that an auto laundry would be preferable to a full corrosion control facility.

The question at this point arises as to what factor(s) caused a dollar loss to appear in the painting activity of the hypothetical consolidated corrosion control work center. Economic theory and the short-run average cost curves of the sample auto painting firms suggest that a savings rather than a loss should have been realized. Several possibilities are suggested.

The man-hours expended by the sample bases on painting activities may have been greater than indicated by the data. The shortcomings of the data, as previously discussed, would seem to lend support to this possibility.

The job standards and frequency of the vehicle and equipment painting cycle for a consolidated corrosion control work center were structured to permit the production of a high quality output. This was reflected in the projected number of man-hours required. It seems possible that some of the individual corrosion work centers in the sample through lack of proper or necessary equipment and/or facilities may have been forced to produce a lower quality output with a subsequent smaller man-hour expenditure per unit of output. The result, of course, would be fewer

man-hours expended for the same quantity, but not quality, of output than the consolidated facility. This type of situation was seen in the short-run average cost curves for the auto painting firms where the firm with the smallest scale had lower, rather than higher, average unit costs than the two larger firms but was unable to produce the same quality of product for lack of one (expensive) piece of equipment.

It is possible that an insufficient number of corrosion work centers were selected for examination. The number selected was limited to four to make data collection possible within the time constraints for this research; however, many other work centers, both maintenance and non-maintenance, are found on any selected Air Force base which could also make use of a consolidated corrosion control facility. It is possible that had the data for additional work centers been included for consideration, the resulting increase in scale of the consolidated facility may well have permitted results other than those obtained.

In summary, then, the results of this research were inconclusive. A consolidated corrosion control facility would seem to offer dollar savings in the form of reduced man-hours required to perform corrosion control and prevention maintenance on vehicles and aerospace ground equipment maintained by a Transportation Squadron Vehicle Maintenance Branch, a Field Maintenance Squadron Aerospace Ground Equipment Branch, and an Organizational Maintenance

Squadron Non-Powered Aerospace Ground Equipment Section on an "average"<sup>1</sup> Air Force base. However, the imperfections in the data and the number of assumptions found necessary, to employ make any such finding tenuous at best. Additional study is clearly indicated.

#### Future Study Directions

The difficulties encountered in this research suggest several areas for further study. A time study at one or more Air Force bases could be made to develop more accurate job standards for the type of corrosion activity considered. An engineering study might be considered with the aim of determining optimum facility size, arrangement, and equipment for a consolidated corrosion control work center. More accurate fixed costs might then be determined. This research did not consider supervisory overhead or organizational structure under the assumption that the consolidated work center could be placed within the structure of an existing organization. However, a management engineering study should perhaps be performed to test this assumption. Finally, a study similar to this research might be desirable to test whether the man-hour data obtained for this research are, in fact, accurate and reasonable.

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<sup>1</sup>The word average is used due to the use, in Chapter 6, of figures obtained by averaging the data from the five bases in the sample.

APPENDIX A  
STRUCTURED INTERVIEW

Air Force Institute of Technology

Thesis Questionnaire

THESIS: SLSR 34-76B

TITLE: A Cost Effectiveness Study of a Consolidated  
Corrosion Control Work Center

RESEARCHERS: Major Donald R. Sellers  
Captain Frank L. Harmon

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1. May the company name be cited as a data source?

2. May your name and/or position be cited as a data  
source?

3. Vehicles processed: CALENDAR YEAR \_\_\_\_\_  
MONTH \_\_\_\_\_ NUMBER PROCESSED \_\_\_\_\_

4. Cost of sales: CALENDAR YEAR \_\_\_\_\_  
MONTH \_\_\_\_\_ TOTAL COST (\$) \_\_\_\_\_

5. Operating expenses: (includes wages and office salaries,  
advertising, customer property damage, equipment lease,  
rent, maintenance and repair, employee compensation,  
group insurance, insurance, accounting and legal fees,  
taxes and licenses, office expenses, payroll taxes,  
telephone, uniforms and laundry, utilities, interest  
and bank charges, depreciation, miscellaneous).

CALENDAR YEAR \_\_\_\_\_  
MONTH \_\_\_\_\_ TOTAL COST (\$) \_\_\_\_\_

5. (continued)

MONTHTOTAL COSTS(\$)

6. Fixed assets: (includes building (or space allocation), operating equipment, office and furniture, leasehold improvements, other assets).

APPENDIX B  
MAN-HOUR STANDARDS, VEHICLE PAINTING

# MAN-HOUR STANDARDS, VEHICLE PAINTING

Quantity	Vehicle	Man-hour Standard
69	Cargo, 1½ Ton	38
75	Metro	40
21	Carry All	40
112	Fork Lift, Small	18
22	Fork Lift, Large	24
150	Pick Up	28
12	Follow Me	37
28	Sedan	28
35	Tractor, Case	20
75	Tractors, Truck	40
26	Tugs	24
7	Dozer	45
5	A/C Towing Tractor	45
7	MB-4	37
6	De-Icer	80
50	Crew Cabs	37
3	Jeep	25
2	Panel, ¾ Ton	42

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